

Sullivan Electrolytic Zinc Plant
Government Gulch, community of Silver King
Kellogg
Shoshone County
Idaho

HAER No. ID-28

HAER
ID
40-KELL,
1-

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Western Region
Department of the Interior
San Francisco, California 94107

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HISTORIC AMERICAN ENGINEERING RECORD

SULLIVAN ELECTROLYTIC ZINC PLANT HAER No. ID-28

Location: Government Gulch, community of Silver King, near Kellogg, Shoshone County, Idaho

U.S.G.S. 7.5 minute Kellogg West, Idaho quadrangle, Universal Transverse Mercator coordinates: 11.562660.5263250, 11.562420.5263090, 11.562260.5263880, 11.562090.5263180, 11.562350.5263360, 11.562480.5263280

Date of Construction: 1926-1928. Additions 1929, 1937, 1948, 1950, 1952, 1953, 1955, 1956, 1957, 1961, 1962, 1963, 1964, 1965, 1967, 1972, 1977. Altered 1958, 1968 (Cell Units A and B), 1969.

Const. Superintendent: Walter K. Mallette

Builders: Williams, Richardson, and Reece
Minneapolis Steel & Machinery
Alphons Custodis Chimney Construction Co.
Illinois Steel Bridge Company
Bethlehem Foundry & Machine Company
Joshua Hendy Ironworks
Union Iron Works
Northwest Lead Company
Kansas City Steel Company
Sullivan Mining Company
Singmaster & Breyer
Leonard Construction Company
Stearns-Rogers Company
Monsanto Corporation
Chemico Corporation

Present Owner: Pintlar Corporation, Kellogg, Idaho

Present Use: Idle Zinc Plant, scheduled demolition to occur in 1994.

Significance:

Internationally, this was the first electrolytic zinc plant to use U.C. Tainton's high current density, strong acid solution process to produce commercial quantities of Special High Grade Zinc (99.99+% pure). This product became the preferred material for the die-casting industry. It served as the standard that the other plants sought to achieve.

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Date:

August 17, 1993

I. Historical and Descriptive Narrative

A. Historic Background- Zinc Processing

Before the twentieth century, commercial production of metallic zinc was limited to retort smelting of oxide ores and roasted sulfides, a pyrometallurgical method that, as recently as 1952, "produce[d] most of the world's zinc".¹ Output from these smelters was utilized as galvanizing material and in alloy production. Zinc is an important component of the copper alloy known as brass, which was used in the manufacture of artillery shells. World War I usage of the stocks of metallic zinc brought about supply shortages, thus driving zinc to an "astonishingly high price" in 1915.² Investigation of an alternative means for refining zinc now became economically attractive to mining and smelting companies, and their efforts pushed development of smelting variations and hydrometallurgical, or electrolytic, production.

Research by Michael Faraday, in the late-nineteenth century, established the laws of electrolysis that metallurgists used to achieve success in producing zinc by this method.³ The basic process involved sulfide zinc concentrates (milled from raw ore), which were "roasted, leached with a sulfuric acid solution, [filtered], the resulting liquor purified, the zinc deposited electrolytically, and the spent electrolyte [regenerated H_2SO_4] used for leaching more ore."⁴ The acid regenerative electrolytic process was marked by the use of low current density (20-30 amperes/sq.ft.) and a weak sulfuric acid strength (5-10%).⁵ It was put into initial operation in low current density plants located at Hobart, Tasmania (Australasia, Ltd.), Trail, British Columbia (COMINCO), and Great Falls, Montana (Anaconda Copper Mining Co.).⁶

The potential availability of hydroelectric energy in the Pacific Northwest was an important factor favoring the use of electrolysis there. A smelting variation (De Laval process) that employed an electric furnace was being used in Norway and Sweden, but these plants were favored by inexpensive hydroelectric power and fuel availability.⁷ For mines like the Star and Bunker Hill, in Idaho's Coeur d'Alene Mining District, electrolytic zinc production presented a means of furthering the development of zinc-bearing ore bodies.

Marketing the zinc oxide obtained by roasting provided an alternative to metal production. The oxide material obtained from roasting sulfide concentrates had a wide variety of uses (i.e. chemicals, matches, enamels, glass, linoleum, oil cloth, ceramics, paints, rubber, shade cloth, automobile tires, and dental cement).⁸ The complex ores of the Coeur d'Alenes, unfortunately, would not easily yield the high purity zinc oxide or leaded-zinc oxide required by the market.⁹ Elimination of the impurities to meet the standards would drive up the zinc oxide costs, erasing the gains of limited processing. Interest in zinc electrowinning, the most

likely means of economically recovering a greater return from their feed sources, was therefore especially appealing to the Bunker Hill & Sullivan Mining and Concentrating Company.

B. Historic Background- Electrolytic Processing and Bunker Hill

In October, 1913, Frederick W. Bradley, president of Bunker Hill & Sullivan, received cathode samples of electroplated lead from the Bunker Hill's manager, Stanly Easton. This electrolytic experimentation by Bunker Hill metallurgists was meant to investigate the possibility of bypassing traditional smelting for a "wet", chemical process.¹⁰ Its results were significant enough to encourage Bradley to apply for patents, and to authorize continued research at the company's North Mill (one of four milling units in the operating area of the Bunker Hill Mine), which was converted into a pilot plant for these experiments.¹¹ The Bunker Hill & Sullivan metallurgists continued their work in electrolysis, eventually directing research toward a sulphate electrolytic process in 1918. That same year, a young metallurgist with a Master of Science from the University of Utah, Wallace G. Woolf, was hired to assist in the work at the North Mill pilot plant. Both he and sulphate electrolysis were to have a long career with Bunker Hill.

Frederick Bradley's interest in electrolysis as an alternative to smelting made him aware of developments in the field, and he took notice of a small-scale zinc plant at Martinez, California, close to his headquarters in San Francisco. U.C. Tainton, a South African metallurgist, had set this plant up in the World War I era, and by 1920, he was in production, with a designed capacity of ten tons per day.¹² Tainton's process employed a high current density (100 amperes/sq.ft.) and a strong acid strength (25-30%).¹³ The patents governing what was known as the Tainton-Pring process had been tested in arguments presented to the German Patent Office by the Langbein Pfanhauser Werke Allegemeine Gesellschaft of Leipsig Sellerhausen in 1912. This electrochemical firm's opposition was countered by several expert opinions that supported the novelty of the process. Professor F.G. Donnan of the University of London stated that he had "made as complete a search as possible of the existing literature on the electrodeposition of zinc on stationary cathodes, and so far as published statements go, these results are new, and could not have been predicted...I am of the opinion that the process of Messrs. Tainton and Pring constitutes an important scientific and technical advance in the successful electrodeposition of zinc from impure, sulphate solutions."¹⁴ His opinion was seconded by Dr. Askenasy of the University of Carlsruhe, who declared that "it has never before been considered possible to obtain from such strongly acid...solutions hard, dense, therefore not spongy zinc deposits when using such high current densities."¹⁵ Tainton and Pring described their process and its 1914 paper presentation before the Royal Chemical Society of Great

Britain. Concurrently, it was being discussed by the American Electro-Chemical Society, one of whose members, O.P. Watts, commented that "Dr. Pring's experiments disclose new and undreamed-of possibilities in the electrometallurgy of zinc, and emphasize the importance of trying experiments which, in the light of our present knowledge of the laws of nature and the properties of matter would seem sure to fail."¹⁶ The "laws of nature" and "matter" were a reference to Faraday's work in electrolysis.

Tainton's and Pring's manipulation of certain factors resulted in zinc being plated. These factors included the introduction of reagents such as manganese dioxide, cressylic acid, and gum arabic in combination with physical guidelines such as temperature, specific gravity, and current density.¹⁷ Careful control of these factors was required to efficiently maintain the electrolytic process. If too much heat was generated, for instance, it created a condition of hydrogen overvoltage during electrolysis. This was marked by drastically reduced plating efficiency.¹⁸ If the factors were controlled, however, zinc was efficiently plated, forming dense, smooth deposits on the cathodes. This resulted in a product that was superior to the zinc metal obtained via the low current density/weak acid process.

In his 1923 report to Frederick Bradley, A.V. Udell estimated a 35-40% savings in capital cost and lower working costs (a more compact plant, simpler operation) if the Tainton process were employed.¹⁹ Perhaps of greatest significance (in terms of the low grade, complex ores of the Coeur d'Alenes), Tainton's process worked well on concentrates bearing a variety of impurities, and in the removal of silica during filtration.²⁰ In his favorable report on Tainton's Martinez plant (which operations he observed in November, 1920), Woolf noted this, especially regarding silica: "The important point in favor of the Tainton process is the fact that it will permit the treatment of...concentrates that may contain an amount of silica prohibitive to the operation of a low acid process."²¹ Generation of gelatinous silica, in filter clogging quantities, was the problem that Woolf wrote of. His conclusions regarding Tainton's work at Martinez helped convince Bradley that this method bore further investigation. As a result, the North Mill pilot plant instituted an investigation of the applicability of this process to Coeur d'Alene District ore, and U.C. Tainton himself became involved on a full-time basis with the work there.

C. Wallace G. Woolf and the Tainton Process

Woolf and his staff began their experimentation with the Tainton-Pring process soon after his return from California. By July, 1921, he was able to issue a report on their work, as applied to concentrates from the Star Mine, in Burke Canyon, at the eastern end of the Coeur d'Alenes.²² The basic steps of roasting, leaching filtration, purification, and electrolysis were common to both

Anaconda's low density/weak acid strength process and Tainton's high density/strong acid strength process, but Woolf was able to verify and expand upon the advantages that he had observed in Martinez, particularly with regard to the "economic advantages in production costs due to the relatively few steps of the Tainton process as compared to the low-acid process."²³

The concentrates at the pilot plant were roasted over an eight hour period, during which time they were raked by a rabble (basically an iron bar with a bent end), until a desulfurized roast, known as calcine, resulted. Although they were working with a small, hand-rabbed furnace (as opposed to the circular Wedge furnaces, with their eight hearths and mechanical rabbles, that the Zinc Plant would use), Woolf estimated that an output 25% greater than that obtained at "Great Falls, Park City (Utah), or at Trail" could be achieved.²⁴ This was because the Tainton process wasn't concerned with the generation of iron ferrite during high temperature roasting, as the higher acid strength facilitated decomposition of ferrites in the leach. Careful roasting, at lower temperatures, (as practiced by Anaconda) to minimize the generation of ferrites, reduced output.

The calcine was leached with sulfuric acid to put the soluble metals in solution. Woolf noted that the "high acid concentration dissolves a greater percentage of zinc from the roasted ore than is possible with low acid strengths, and accomplishes this moreover with but one leaching treatment."²⁵

Following the leach, the pulp had to be filtered. Use of vacuum drum filters, such as those manufactured by Dorr-Oliver, was the standard practice at the electrolytic plants of that era. These were large, revolving drums, with a filter-cloth attached to the periphery. The filter drum was partially submerged in a reservoir into which the slurried pulp was continually introduced. Within the drum's interior, a vacuum drew the slurry onto the filter cloth and captured the filtered solution. As a cake formed on the exterior of the cloth, the filter revolved down to the discharge point where the vacuum was removed and air pressure applied to loosen the material. A scraper bar finished the removal of filter cake.

Maximum extraction of zinc solution in filtering was the goal, but the continuous filter left higher than acceptable zinc values in the cake. As a result, Woolf and Tainton experimented with a small batch filter modeled after the Burt filter. Woolf reported that "while the small filter used in this test differs in some mechanical details from the standard Burt, it does not do so in the important principles, such as the design of the filter leaves, the method of applying pressure and of cake formation, feeding, etc".²⁶ The "filter leaves" that Woolf wrote of were canvas cloth encased, fluted boards that lined the interior circumference of the filter. Leach pulp was admitted at the feed end of the filter, the filter revolved, and air pressure was applied. Filtrate discharged from outlet nipples which were an integral part of the filter boards.

Subsequent applications of wash water to the filter extracted additional zinc values from the filter cake. To Woolf, the clear advantage of the Burt filter was that it "undoubtedly is able to make a more perfect washing of the soluble zinc from the residue than the Oliver or any standard type of continuous filter."²⁷

The filtrate that was discharged from the test filter had to be purified of copper, cadmium, and cobalt. Of these metals in the Star concentrates, Woolf found cobalt and cadmium the more prevalent, and that "cobalt gives the greatest trouble...in the low-acid process, working at room temperatures or slightly higher, cobalt will not precipitate upon zinc dust; with higher temperatures such as the Tainton Process employs cobalt is precipitated upon zinc-dust, especially in the presence of a metal having a large potential and thus forming a 'couple' with the zinc. Copper is used for this purpose and copper sulfate is added to the solution in addition to the small amount already present and derived from the ore."²⁸ It is not apparent from Woolf's report when the copper sulfate was introduced into the purification agitator tank that received the Burt filtrate, but he did state that "the copper sulphate added in our tests at the North Mill averages 0.7 per cent of the weight of the zinc in solution (140 lbs. copper sulphate per ton cathode zinc)."²⁹

The zinc dust that was added to the agitated filtrate precipitated impurities out of solution by virtue of zinc's position in the electromotive series. Copper, cadmium, cobalt, and other metals present in the solution were lower in the series, thus the zinc dust addition caused them to precipitate out of solution. The precipitated impurities were captured during filtration, which resulted in a high purity, neutral zinc sulphate solution. The purity of the pilot plant's neutral solution was evidenced by the high purity electrolytic zinc metal obtained through electrolysis.

After the ZnSO_4 had been purified, it was pumped into a neutral storage tank. From there, the neutral solution was added to spent electrolyte from the electrolytic process (that had been returned to a balance tank) to build a solution that contained 200-210 grams per liter of zinc and that was 20-28% sulfuric acid (H_2SO_4).³⁰ It was introduced into a lead-lined box, or cell. Zinc was electrolytically recovered on aluminum cathodes spaced between two perforated lead anodes (provided for each cathode) contained in the cell. An electric current that produced a 100 ampere per square foot current density on each face of the cathode passed through the cell, causing the zinc that was in the solution to deposit on the cathodes, while regenerated H_2SO_4 increased the acidity of the electrolyte. Plating was allowed to continue for a 12-hour period, "although 24 hour plates have been made without loss of current efficiency."³¹ Woolf duplicated Tainton's use of glue as a reagent in the electrolyte, which W. C. Smith (of U. S. Metals Refining Company) had observed during his visit to Tainton's plant, noting that the addition of glue at the Martinez plant had been found to give "a much smoother deposit," while permitting

hydrogen gas "to be freed as much smaller bubbles, thereby causing less acid mist in the cell room."³²

When the North Mill metallurgists' first successfully plated zinc had been melted in a small furnace, Woolf and Tainton presented the "silvery lump...to Stanly Easton, who for years showed it proudly in his office."³³ The results obtained by Tainton at Martinez had been successfully duplicated by Woolf, Tainton and their crew at the North Mill, and Woolf was able to report that "the electrolysis can be successfully maintained under the Tainton high-acid, high current density conditions with very much less irregularity caused by impurities than is possible under the conditions being used in electrolytic zinc plants now built."³⁴

The metallurgical success that they had achieved was a result of careful application of the process steps to Star Mine ore. By the time the zinc sulfate solution reached the electrolytic cells, it was of such a high-purity that electrolysis produced zinc of "premium grade, containing the necessary minima of cadmium, iron and lead."³⁵ Reassured by the initial work at the North Mill, Bradley and Easton could proceed with plans for utilizing the zinc-rich feed from mines like the Sydney and Constitution (of the nearby Pine Creek drainage) and the lower ore-grade Star Mine. An important part of their strategy in Burke Canyon involved the neighboring Hecla Mine (owned by the Hecla Mining Company). Earlier, in April, 1921, Bradley had offered Hecla's directors a chance to participate in a venture known as the Sullivan Mining Company.³⁶

D. Formation of the Sullivan Mining Company

Frederick Bradley first became involved with the Star Mine during the course of a lawsuit brought by its owners against Federal Mining & Smelting Company. The Star alleged trespass, claiming that Federal was mining Star ore from the adjoining Morning Mine. In return for a loan to sustain their court battle, the Star's owners entered into an agreement on February 10, 1917 that gave Bradley stock in the mine, with an option to purchase the Star.³⁷ Later that spring, Bradley organized a new mining entity, the Sullivan Mining Company, to which he assigned his rights in the Star.³⁸ Joining Bradley as directors in signing Sullivan's Articles of Incorporation were Jules Labarthe, J.S. Wallace, Myron Folsom, and Stanly Easton. All of these men were closely affiliated with Bunker Hill: the firm of Bradley, Bruff, and Labarthe had superintended the construction of the Bunker Hill Lead Smelter in 1916-17; Wallace was the assistant treasurer of Bunker Hill; Folsom acted as an attorney for Bunker Hill; and Easton was its long-time manager. Sullivan's primary purpose was to be the organizational entity for exploitation of the Star's ore, and those plans were to later include a plant for the production of metallic zinc. The Star Mine's role in this future hinged upon continuation of its ore body at depth and access to that ore. Time proved

geological prediction correct on the first score, but the problem of access required practical solution in short order. Toward that end, Frederick Bradley had commissioned a study, in October, 1920, of the mine's economic geology by Oscar H. Hershey (who had performed a similar study of the property in October, 1917).³⁹ Hershey found four potential routes for reaching the ore of the lower levels: The first, and quickest, would be to access it via the Morning Mine's No.6 tunnel, provided an arrangement could be worked out with Federal; a second possibility lay in extension of the Black Bear Mine's tunnel from Burke Canyon; the third method would require extension of a tunnel from the Hecla Mine in Burke; and the last possibility would entail driving a new tunnel from Grouse Gulch into the Star vein.⁴⁰

Bunker Hill had a history of litigation with Federal going back to the turn-of-the-century, and Federal was the Star's opponent in the trespass suit, so the first option posed difficulties. Hershey objected to the Black Bear route on the grounds that it would "have a number of awkward bends and will hardly be large enough to handle large ore trains through it."⁴¹ He also objected to the Hecla tunnel's higher altitude (than the Black Bear).⁴² It is not known what objections were posed by a Grouse Gulch tunnel, but this route wasn't exploited. In the end, the Hecla tunnel extension seemed the most practicable, and Bradley approached Hecla in April, 1921, proposing that they join Bunker Hill as a partner in the Sullivan Mining Company.⁴³ Not only would this facilitate development of the Star Mine, but it also provided Bunker Hill with a potential partner in the subsequent development of the Zinc Plant.

Hecla's directors presented this offer to their shareholders at the company's annual meeting in May, and by August 10, 1921 they tendered Bunker Hill a check for \$99,504.59 in accepting the proposal, thus gaining a half-interest in the Sullivan Mining Co.⁴⁴ An agreement was formalized the next day, but, on August 17, dissident shareholders, led by Hecla director Sarah Smith, sought an injunction against Hecla's participation in the Sullivan. After court arguments had been heard regarding the issue, the Sullivan contract was found valid on February 3, 1922.⁴⁵ The Sullivan Mining Company was then free to develop the Star Mine, the extensive zinc-lead orebody of which would be central to plans for a Sullivan Electrolytic Zinc Plant.

E. Factors in the Development of the Sullivan Zinc Plant

The output of the Star Mine came from a large, low grade zinc ore body. Only high grade portions, sold at a high zinc price, could assure its operators of a profit after treatment at the low density plant operated by Anaconda at Great Falls, Montana. For this reason, A.V. Udell could state, in 1923, that "the successful outcome of the Star Mine venture is believed to rest entirely on the construction of a local zinc plant."⁴⁶ After further analysis

of methods of operation, Udell proposed that "the Tainton process of electrolytic treatment shows to the best advantage as to economic outcome."⁴⁷ Udell, president of Tainton Industries Corporation (the organization formed to control the licensing of Tainton's process) could make this statement on the basis of the work performed since 1921 at the North Mill pilot plant under the direction of Wallace Woolf and U.C. Tainton, with the assistance of the Martinez plant superintendent, Daniel Bosqui.

When Hecla had established its interest in Sullivan, their president, James McCarthy, set crews to driving the needed tunnel into the Star workings. This task was completed by November, 1924, when they encountered the Star ore vein, with production from this area commencing in 1925.⁴⁸ With the assurance of a steady feed supply, planning could go forward on the proposed Sullivan Electrolytic Zinc Plant. Concurrent with this, Tainton "conceived the idea that possibly a purer grade of zinc could be made by altering some of the elements of the process."⁴⁹ The earlier work had established the applicability of the process to Coeur d'Alene District ores, and a product comparable to that made by established electrolytic plants had been obtained. Manufacture of high purity zinc (to a standard of 99.90% purity) then became the goal to which efforts were directed in late 1925, when work at the North Mill was renewed.⁵⁰

Woolf and Tainton gathered a staff of metallurgists and research assistants to examine the varied facets of the Tainton method. E.R. Crutcher came to work at the North Mill, bringing experience gained at Australasia (in Hobart, Tasmania) and Anaconda; Henry P. Ehrlinger II, a young graduate of the University of Wisconsin, was to conduct important research regarding the anodes; C.M. Palmer contributed metallurgical expertise in the area of additive agents; and Gregory Popoff, who went on to a long career with the Sullivan Mining Company, aided in the work done in the pilot plant. They were assisted by men like A.B. "Curly" Henwood and Emmett Waltman, who, like Popoff and Crutcher, transferred their North Mill experience to the operations of the Zinc Plant.⁵¹

All sections of the process operation were scrutinized: In roasting, they sought to make "as little of the undesirable zinc ferrite as possible and...enough zinc sulphate (which was water soluble) to make up for plant acid loss thru [sic] mechanical and chemical reactions"; impurity limits for electrodeposition were determined, the result being that "these impurities would have to be removed...in the leaching or purification units"; and electrolysis research produced further advancements in production efficiency and control of the electrolytic process, for the exceptionally pure zinc that was plated "revolutionized the industry...it gave the die casting industry the metal that they most desired."⁵²

To ensure sufficient acid regeneration to make up for losses, a 2.5% level of zinc sulphate in the calcine was established.⁵³

As for the presence of ferrous iron, work in the leaching section "indicated that if a batch leach were carried on past the neutral point in the first stage, re-acidified with a small amount of acid and then taken to neutrality as the final step, most of the iron was precipitated as ferric hydrate."⁵⁴ Silica was also precipitated, in a gelatinous form. Addition of a small amount of fluorspar (calcium fluoride) dehydrated the gel, allowing filtration of the leach product.⁵⁵

In purification, use of copper sulfate, in combination with zinc dust, greatly aided in removal of cobalt. Ehrlinger noted that this effected "a shortening of the time required to complete the reaction."⁵⁶ Additional use of zinc dust removed the copper.

The work in the electrolytic section benefited from improvement in these prior steps, and the modifications made in that department helped to provide the pure zinc for which Sullivan was to be recognized. One of the metallurgists' concerns was the tendency of the lead anodes to warp, a condition that was more marked in the pilot plant's high-acid method than in the low-acid plants then operating. Henry Ehrlinger was involved with the work performed to correct this, and those investigations led to the study of alloys as a means of strengthening the anodes. After extensive work on more than fifty alloy combinations, an anode composed of 1% silver and 99% lead was selected.⁵⁷ Ehrlinger experimented with anodes that had a silver content as high as 2.6%, but anodes with 1% silver produced the desired results without the greater cost of higher silver composition.⁵⁸

The use of certain chemical additives gave the finished result that Woolf and Tainton were looking for, zinc of an exceptionally pure nature. Glue had been used as an addition agent to facilitate smooth zinc-plating, but tests substituting silicic acid (SiO_2) for glue produced "excellent deposits," with a purity of "99.985% by difference."⁵⁹ An added benefit of the use of silicic acid was improved current efficiency (3-5%), which "lowered the power consumption materially for it not only increased the current efficiency but it lowered the terminal voltage."⁶⁰ After the silicic acid had proven useful, gum arabic was added to the cell solution, as "it was generally known that certain colloids of the gum family worked with some success...in electrolysis."⁶¹ The results were exceptional, as the grade of zinc had now improved to 99.99+% pure.⁶²

One final problem existed regarding the electrolytic cells. In the process of electrolysis, an acid mist was released into the air above the cells. This phenomenon could not only prove damaging to the plant physical facilities, but it would be hazardous to the health of the plant workforce. Again, extensive research was conducted. A variety of oils were experimented with to find a frothing reagent that would capture the fine bubbles (that formed the mist) in larger bubbles, which would harmlessly pop at the cell surface. Poor results were obtained until C.M. Palmer came up with the idea of making an emulsion of cresylic acid with the gum arabic

being used in the cells. This combination relieved the acid mist problem at the cost of a slightly lowered current efficiency.⁶³

Woolf was also aware that the work performed at the pilot plant was adapted from Tainton's small capacity Martinez plant. Operations on a larger scale would obviously entail further modifications. One facet of this was the need for an electrolyte cooling system scaled to the enlarged Zinc Plant. In a memo to Stanly Easton he addressed this when he wrote that a "decision has been reached that a modification of the design of lead pipes laid upon tables, as was used at Martinez, is necessary. Tests have been made with coolers designed by Mr. Tainton and further tests are now to be made which he has outlined. In conference with Messrs. Mallette, Bosqui, Tainton, and myself, it has been decided to make a series of tests at the North Mill, as a result of which we hope to secure the necessary data for the proper design of the zinc plant electrolyte cooling system."⁶⁴

Frederick Bradley was kept informed of developments at the North Mill by Stanly Easton, and he wrote back, expressing his concerns with the various aspects of the project, not the least of which was control of the Tainton process, which, Bradley feared, was being expropriated by the Anaconda Copper Mining Company. In March, 1925, he called Easton's attention to "the editorial on page 355 of Engineering and Mining Journal-Press of 28th ult. saying that the Anaconda Co. has boldly appropriated the Tainton ideas for hot-strong acid solutions and for high current density. The editorial goes on to say that the Anaconda Co. has watched with approval our pilot work at Kellogg in spite of the fact that they denounced it to some of our own people as impracticable."⁶⁵ Woolf noted Anaconda's actions, too, when he wrote to Tainton in London the following year, advising him of Anaconda's experimentation with high current density (while claiming not to have increased acid strength), and urging him to contact his attorneys and "make known the poaching of...Anaconda upon your private preserves."⁶⁶ Tainton referred to the developments at Great Falls in a January, 1927 letter to R.E. Phelan regarding a roasting test. Anaconda hadn't been receptive to inquiry by Phelan, and Tainton remarked that he wasn't surprised, as "we have been informed by both Trail and Anaconda, especially from the latter, that the doors are shut as far as visits from our men are concerned. The only point which I am not sure about is whether they wish to keep information from us on the ground that it might be helpful to us or whether because it might be awkward for them. At any rate, I can promise you more hospitable treatment in Kellogg when our own zinc plant gets into operation."⁶⁷

This situation was contrary to prior experience with Anaconda, as A.V. Udell had been well received when he visited the Great Falls zinc plant in August, 1921, as part of his process investigation for Bunker Hill. Anaconda had pushed adoption of their process, offering to assist in the design and construction of

the plant, pointing out their established operational data (as opposed to the "experimental stage" of Tainton's work), holding out the possibility of experienced labor and marketing facilities, and noting that "a very favorable power contract could be secured from the subsidiary Montana Power Company."⁶⁸ Conversely, it was inferred "that should we utilize some other process we might possibly be held up on power contracts and also run the possibility of patent infringement litigation."⁶⁹

A power contract was a particularly crucial element in the operation of an electrolytic zinc plant. Bradley had combated a 1923 rumor about suspension of the project by saying that "we are going right ahead with a unit of the proposed zinc plant, as soon as we have secured the necessary power contract."⁷⁰ Washington Water Power was the nearest and most likely company to supply the needed power, but Udell received a competitive rate quote in a letter from J.D. Ross of the Seattle Lighting Department, which Bradley passed on to Easton.⁷¹ Undoubtedly, Bunker Hill was trying to obtain the best possible rate for what would be a large operating expenditure, but Anaconda's threat apparently had some weight, also. Bradley expressed his thoughts on this to Easton in late-1924: "As Tainton writes that the Great Falls 200-ton zinc plant is now getting all the easy feed it requires, perhaps the Anaconda Co. may relent enough to let the W.W.P. furnish us power enough for a little 25-ton plant to work a difficult feed."⁷²

Anaconda's influence was limited, however, and negotiations with D.L. Huntington of Washington Water Power took place over a four-year period, from 1923-27. Woolf regarded Huntington's willingness "to eliminate all participation by his company in the profits of the zinc company above a certain return (as) a concession of great value to the zinc enterprise," but he was uncomfortable with Huntington's insistence on a minimum rate of 4 mills per kilowatt hour.⁷³ The contract that was signed on March 27, 1927 by Hecla's James F. McCarthy (as president of Sullivan) and Washington Water Power's vice-president, M.W. Birkett fixed payment on a sliding scale between a minimum 4 mills and maximum 5 mills per kilowatt hour. Increases were bounded by a price for zinc spelter that ranged from five to ten cents a pound and a wage basis of \$3.25 to \$6.00 per man per day.⁷⁴ Sullivan Mining Company was guaranteed a source of power for the plant that had been under construction since the summer of 1926.

F. The Sullivan Electrolytic Zinc Plant: Construction and Operational Layout

Walter K. Mallette was the Superintendent of Construction for the plant that began to take shape in September, 1926 on the eastern hill slope above Government Gulch, a mile south of the Lead Smelter. The general plant design had been determined, and benches were being graded for the placement of the various process elements of the plant. Mallette stressed the importance of the design

details of the project (he envisioned a need for 10-12 draftsmen) in his October, 1926 construction report to Easton: "To secure an entirely satisfactory plant will require careful engineering and designing. We cannot approach this problem with the same degree of confidence with which we could approach the design of a concentrator or a smelter. Every step in the process, as well as every machine to accomplish that step, must be considered from every angle and all assumptions or unproven theories must be eliminated. We are dealing with a process which is more delicate than either smelting or concentrating and the careful operation secured in a laboratory or test plant must be closely duplicated in this commercial unit in which the operatives will be ordinary grades of labor rather than chemists."⁷⁵ In keeping with that spirit of slow-going caution, Mallette assured Easton that the plant was going to be arranged in such a fashion that, should the Tainton process fail commercially, it could be remodeled as a low density operation.⁷⁶

In his November 1, 1926 construction report, Mallette reiterated what would be an ongoing source of trouble- design related problems: "We are experiencing difficulty in procuring competent designers and draftsmen. After much seeking we now have a structural steel designer en-route from Chicago, having secured this man from the Illinois Steel Bridge Company, who have released him for the few months that we may require his services."⁷⁷ Steel and concrete were the major structural materials of the plant being raised in Government Gulch. Mallette informed Easton that a local firm, Williams, Richardson, & Reece, had been awarded a contract for concrete work. Concurrent with this, decisions were being made regarding plant equipment, and Mallette noted that "the Wedge Roaster was selected and an order has been placed for the iron and steel-work for five of these."⁷⁸

By mid-January, 1927, much had been accomplished in grading, and foundation work. Preparations for the roasters had reached the point where an order had been placed for the fire brick for these with the A.P. Green Fire Brick Company of New Mexico, Missouri.⁷⁹ Mallette was still seeking draftsmen to advance the pace of the detail design work, finally securing an additional man, with two more promised in February.⁸⁰ One of the men Mallette had acquired as a design engineer was O. J. Jasberg. He worked on plant and process equipment design requirements, spending three months at the Joshua Hendy Ironworks in San Francisco implementing the design, fabrication, and testing of Burt filters. This work effected the required processing results for the Leach filtration. He later became Chief Engineer for the Sullivan Zinc Plant, filling that position until his death in 1958.

Winter weather slowed construction progress, and an outbreak of influenza in February posed further problems, but many design details were clarified and construction work continued to progress. Minneapolis Steel and Machinery won the contract for the fabrication and erection of the "structural steel comprising the

two main structures at a price of \$4.98½ per cwt. erected on the foundation."⁸¹ Bethlehem Foundry and Machine Company were due to ship the first roaster components in March, 1927, and Mallette's staff had begun the task of performing calculations necessary for the Cottrell treater and stack design.⁸² Addressing a critical area, he noted that "we are endeavoring to locate a good electrical designing Engineer for power plant layout, wiring, and switchboard work and such items. This is an important feature of our plant and requires a good man to get the best results in design."⁸³

The continuing proliferation of details requiring close scrutiny led Mallette to remark on July 19, 1927 that "progress has been discouragingly slow owing to the inability to get and retain draftsmen and designers. There are so many new and intricate engineering problems to be solved in connection with this plant that an unusual amount of work must be done in the drafting room. This, coupled with the difficulty of obtaining good men, has delayed our progress materially."⁸⁴ Still, work progressed, and in that same report he wrote to Easton that residences were being planned for salaried personnel, and that a "contract was let to the Alphons Custodis Chimney Company for a 250 ft. by 14 ft. diameter radial brick stack with acid proof lining of vitrified brick."⁸⁵

Rendering the working surfaces of the plant acid proof was a vital consideration. The higher acid strengths employed by the Tainton process guaranteed a corrosive environment in process areas like Leaching and Electrolysis. To deal with this, lead sheeting and acid-proof bricks and materials would be used where required. The technique for welding sheet lead in place was known as "lead-burning," and in October, 1927, Mallette wrote that a contract for this "was closed with the Northwest Lead Company for the lead work on the entire plant. One car of sheet lead has been shipped and lining of storage tanks will start at once."⁸⁶ The tanks in Leaching were what Mallette was referring to, along with Cell Room feed launders, electrolytic cell boxes, sumps, and the concrete floor below the cell circuits. Pump impellers that moved the electrolyte would have to be fabricated out of lead. The finished plant would require a lead-burning crew for the maintenance of the areas that utilized lead protection. Fortunately, as Wallace Woolf was known to remark, the Zinc Plant could take advantage of the Bunker Hill Lead Smelter, reclaiming lead which had reached the end of its useful life (that which was broken or unsuitable for corrosion protection) in exchange for new sheet lead.⁸⁷

By late-summer of 1927, Mallette wasn't in a position to offer a firm date on completion, but he speculated that "unless unforeseen [sic] delays occur operations should start early in 1928. Every effort is being made to effect this at the earliest possible time and, as practically all of the plant will be under cover in another sixty days, there should be little or no delay due to inclement weather."⁸⁸ The structural steel was being riveted in place, and concrete work had reached an advanced state, so the crews could turn their attention to covering the framework with wooden roofing

and gunite walls (a cement mixture applied over wire reinforcing with a cement gun). This form of construction had been used previously by Bunker Hill at the Bunker Hill Mine. It was to be replaced in post-World War II era plant construction with cement asbestos shingles over a wooden framework.⁸⁹

During the summer and fall of 1927, wells were sunk in the aquifer of the South Fork of the Coeur d'Alene River and water was obtained from the stream in Government Gulch to fill a reservoir that was being built at the plantsite early in 1928, providing the plant with a 3000 gallon per minute supply.⁹⁰ The water was needed for cooling electrolyte to a temperature that held cell operating parameters where they belonged for efficient cell circuit operations. It was also used for other process operations and for fire protection.

Mallette's estimate of plant completion by early 1928 wasn't realistic, as he still struggled with a shortage of draftsmen for the backlog of design details, and equipment trickled in. They received four of the six Burt filters being manufactured by Joshua Hendy Iron Works of San Francisco in February, 1928, but were still awaiting the agitator mechanisms for the Leach and Purification tanks from Union Iron Works in Spokane, Washington. His report to Easton for that month included progress notes on the electrolytic division where "cells are nearly all in place. Gunite work is nearly completed except for outside. Busbar has been ordered and should be received about the 20th. Lead work on cells will start shortly."⁹¹ The many pieces of a complex process were slowly being assembled, and the Sullivan Plant was close to becoming a working reality.

Work continued throughout the spring and summer of 1928 on the various elements of the plant. By June, 1928, most of the construction work had been completed (see Photograph ID-28-1), with the exception of the Cottrell treater, which was being erected at that time. The operating details that had been refined in pilot plant testing were being adapted to the larger scale of the various process areas of the Zinc Plant. The long awaited start of operations was close at hand.

An accounting worksheet for September, 1928 showed the first results of production, with Leaching residues valued at \$31,171.23 being shipped to the Lead Smelter.⁹² Power was turned into the cells on October 8, 1928, and the Sullivan Electrolytic Zinc Plant was officially up and running on November 5, 1928, approximately six months behind the revised startup date. It was designed to produce 50 tons of slab zinc per day. In addition to the Upper and Lower Plant main buildings, a Cottrell treater (with Stack), Boiler House, Machine/Welding Shop, Warehouse, Research and Analytical Laboratories, Dry House, Electric Shop, Company Garage, Plant Office, and six residences for supervisory personnel had been constructed. With the exception of the Electric Shop, Dry House, Office, and residences, these facilities were to the south of the Upper Plant. The Electric Shop was situated adjacent to the power

substation and the Generator Room of the Lower Plant. The reservoir, situated to the south of the Generator Room, was flanked by the Dry House and Office on the east and south. The residences formed a semicircle across the road from the Plant Office.

As originally conceived, the completed Zinc Plant was designed to produce an output of 50 tons of slab zinc per day. Space for increased production capacity was part of the original design. The complex stairstepped down a seventeen degree slope, utilizing gravity flow, wherever possible, to reduce the need for re-elevation of the process materials. Concentrates, arriving via rail car, were offloaded into concrete storage bins (1200 tons total capacity) at the top of the Roasting department.⁹³ From the bottom of the concentrate bins, apron feeders supplied a conveyor belt, which passed the concentrates over a weightometer before dropping them through "a set of 30x12 in. rolls to break up lumps."⁹⁴ A screw conveyor fed the material to a bucket elevator, which discharged to a tripper conveyor that delivered concentrates to roaster feed hoppers as needed. The tripper conveyor's direction of travel was reversible, allowing the stocking of the various roaster feed hoppers along its path.

The roasters were 25 feet in diameter, each with a top drying hearth and seven roasting hearths in vertical succession. Fuel oil burners were set on the number five and seven hearths (with portable burners available for other hearths) to provide the initial heat for ignition of the sulfur in the ore and supplemental heat to maintain the roasting process when insufficient sulfides were present.⁹⁵ As the concentrates were roasting, air cooled rabble arms, "attached to a central revolving shaft, rake[d] the ore toward the center of one hearth" where it fell through a drop hole "to the next lower hearth. Here it [was] raked toward the outer edge where it, again, drop[ped] to the next lower hearth, and so on until it [was] discharged at the bottom hearth as calcine."⁹⁶ Roaster emissions entered a 10-foot wide steel balloon flue, which traveled 1100 feet to a dry Cottrell treater situated at the top of the ridge, 400 feet above the roasters. After precipitation of dust that had been entrained in the gas stream, the gas escaped through a 250-foot high brick stack.

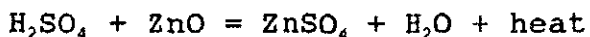
The Cottrell treater housed vertical ranks of steel plates and wires, organized in two units, "each having five sections in series, so that the gas is treated five times."⁹⁷ Four rectifiers supplied the electric current that passed through the wires. As the Roaster gases traveled through the series of plates and wires, dust in the fume was electrostatically precipitated onto the plates, being repelled by the positively charged wires. The current was discontinued from the power source and the plates were mechanically rapped at periodic intervals to release the dust. The Cottrell dust and dust accumulations in the balloon flue were then collected and returned for re-roasting.

Jacoby conveyors transferred the calcine from the Wedge roasters to an elevator, which dumped it onto a vibrating screen.

Undersize material passed through the screen and was conveyed to storage bins in Leaching. The oversize material was passed back through crushing rolls and returned to Roasting with the recovered flue dusts.

The stored calcine was conveyed by a screw conveyor to another bucket elevator, which supplied a distributing screw conveyor that, in turn supplied the charge bins above the Leach tanks. In the original Zinc Plant, three charge bins supplied each one of the three leach agitator tanks. The bins held respectively ferrite, oxide material, and manganese dioxide, and were "of 10-ton capacity...equipped with individual feed, the entire unit being carried on Fairbanks dial scales so that the weights fed into the agitators [were] read directly by the operator."⁹⁸ The ferrite was a result of the magnetic separation that was part of Tainton's original process employed at Martinez.⁹⁹ Woolf noted that Tainton employed a magnet to separate ferrite zinc from oxide zinc so that "the difficultly soluble ferrite portion" was added "at the beginning of the leach to give this portion the benefit of the strong acid."¹⁰⁰ The more readily soluble oxide portion was added as the strength of the acid was depleted. Magnetic separation was part of the original plant process at the Sullivan Zinc Plant, but it was discarded in 1929.¹⁰¹ Manganese dioxide was added in the leach "in order to have all of the iron in solution as ferric iron so that it may be eliminated."¹⁰² Addition of manganese dioxide caused a reaction whereby ferrous iron was oxidized to a ferric state. As calcine additions brought the leach solution to a neutral ph, the ferric iron precipitated out of solution.

Return electrolyte from the electrolytic cells and the charge materials were agitated in 20 ft. diameter by 14 ft. deep tanks, that were heated with lead pipe steam coils, until the leaching was completed. The agitator mechanism consisted of "a main drive shaft supporting a radial beam just above the maximum solution level."¹⁰³ Lead-coated iron pipes were attached to the beam, extending downward to a point four inches from the tank floor. There, pipe pairs were attached to cast lead bases, thus forming "muller" arms.¹⁰⁴ Rotation of the mechanism served to mull, or keep the pulp in suspension. The steam coils heated the 30% H₂SO₄ electrolyte and maintained the leach temperature. The heat of the chemical reaction between calcine and electrolyte raised the leach temperature to the boiling point, at the same time extracting the zinc from the calcine and putting it into solution. In this manner, a neutral pulp, rich in zinc sulphate was formed. Represented chemically, this was the basic reaction:



To ensure that all of the iron content was precipitated, the leach was slightly reacidified and more calcine gradually added to precipitate the remaining iron. Periodic testing of the pulp by the leach operator monitored the progression of the batch leach and

signaled its conclusion, three to five hours after the process had begun. The leach pulp was then gravity slurried into storage tanks where it was agitated to maintain suspension until being gravity fed into the Burt filters.

The six 5 ft. diameter by 40 ft. long Burts occupied a large section of the southern half of the Filter Floor in the Main Building of the Upper Plant (See Photograph ID-28-2). These were the full-size units that Woolf and Tainton had modeled their North Mill test filters after. They were a "rotary, internal pressure type of filter" that allowed the addition of heat (which prevented crystallization of the solution) and multiple washings for efficient extraction of dissolved metals from the pulp.¹⁰⁵ The filter shells were copper-lined, with a bull gear around the feed end of the filter and a riding ring bearing near the discharge end. A pinion gear meshed with the bull gear, and power for rotation was supplied by 35-h.p., three-speed motors. Leach slurry, "wash waters, and air for carrying on the filtration [were] all admitted through the hollow trunnion at the head end of the filter."¹⁰⁶ Sixteen 20-foot long fluted filter boards were arranged around the shell's interior, running from the feed end to the center of the filter. The boards were encased by canvas filter cloths. Sixteen identically arranged and cloth covered filter boards extended from the discharge end to the filter center. Each of the fluted filter boards had an integral filtrate outlet nipple that discharged filtrate to a filtrate collection launder located below (and at the center of) the filter. When the filter had been filled with leach slurry, rotation was begun and air pressure was applied. After all of the filtrate had discharged into the collection launder beneath the outlet nipples, air cracked the filter cake that accumulated on the canvas and blew through the pipe nipples. At this time, the first wash water was introduced through the feed end. Sufficient quantities of dissolved zinc were removed from the filter cake by this wash to warrant adding it to the initial filtrate, which had been fed by the collection launder into a distribution launder that supplied the Burt solution surge tank. Air blowing through the nipples alerted the operator to start the second wash. By shifting the collection launder's position, the filtrate from it was conveyed through a separate launder to the first wash water storage tank. Admission of the third wash water occurred when air passed through the nipples again, and another shift of the collection launder fed filtrate to a launder that supplied the second wash water storage tank.

The filter cake that had been retained on the canvas cloth was repulped by the addition of water from residue thickener tanks located outside and west of the Filter Floor. As rotation continued, vacuum pressure was applied to loosen the filter cake from the cloths. When it was completely repulped, the discharge end ports were opened and the slurry ran into a launder that conducted the leach residue into the thickener tanks. A subsequent addition of water was used to wash any residual material through

the discharge ports, which were then closed, and air pressure blew the remaining water through the discharge nipples. The Burt filter was then ready for the next batch some three to four hours after filtering had begun. The Burt filters were each capable of processing 70-130 tons every 24 hours; output below 70 tons indicated a need for new filter cloths.¹⁰⁷ During filtration, the operator checked the filtrate discharge nipples for signs of residue discharge. If residue was escaping through a nipple, that indicated a break in the canvas filter cloth. To remedy this, the Burt operator would stop the filter and hammer a bung into the pipe nipple to seal off that particular filter board. Leak correction could be repeated in this manner, until the filter was shut down for mechanical servicing and replacement of the filter board assemblies. Photograph ID-28-3 shows a Burt filter at the Joshua Hendy Ironworks, after it had been fabricated and checked out, prior to shipment to the Zinc Plant.

The Burt filter residue was recovered for shipment by railroad car to the Bunker Hill Lead Smelter. It contained lead, silver, and gold, thus it was a valuable feed source for the smelting plant. Tank overflow from the two 30 ft. diameter by 9 ft. high Dorr thickener tanks was stored for repulping succeeding Burt filter cake, and the thickened product was pumped to the Residue Floor at the base of the Upper Plant where three Oliver vacuum drum filters reduced it to a cake that was sent to "two...oil-fired Ruggles-Coles dryers, where the moisture content is reduced to approximately 20 per cent."¹⁰⁸ Filtrate from the Oliver filters supplied the "mull", or third, wash water tank. The dried residue was loaded into rail cars at a siding to the immediate west of the Residue Department.

The Burt filtrate and first wash water traveled by gravity into a Burt filter surge tank from which the solution was pumped into heated Burt solution storage tanks north of the Leach Department. These tanks supplied the Purification tanks north of the Burt Filter Floor with a solution charge. There, the zinc sulphate solution was treated in three 22 foot diameter by 12 foot deep wood stave purification tanks that were heated by steam coils.¹⁰⁹ Burt filter solution was drawn from storage into the first Purification tank through a six-inch diameter copper pipe that was "fitted at the discharge end with rubber hose and pinch cocks, instead of valves."¹¹⁰ As in Leaching, a paddle agitator mixed the heated solution, with copper pipe being used in the agitator mechanism, instead of lead. Zinc dust was added, and the precipitation of copper began to take place. Copper was almost completely taken out of solution in this first tank, the contents of which were filtered through a Shriver press "having 35 frames [and 34 grid plates], each 36 in. square."¹¹¹ The metal grid plates and frames were vertically mounted in an alternating series within the press mechanism. A filter medium of "10-oz. canvas duck", backed by "30-lb. Kraft paper" was used between plate and frame.¹¹² The canvas provided strength for the filter media, and

the paper provided the effective filtration media. To seal the press, 100 lb./square inch pressure was applied to the filter press by a hydraulic closing ram at the end of the assembly. Solution from the purification tank was pumped through an inlet valve and pipe on the feed end, filtering as it traveled through the grid path, escaping via an outlet valve and pipe on the feed end. When the batch had finished filtering, the slurry valve was closed, and an air valve opened to blow out the press. After the air was shut off, the hydraulic ram was released to allow movement of the plates and frames along the assembly track. The caked residues were released by the press operators, who manually released and shook each frame, causing residue to fall through a discharge chute under the filter press. This residue collected on the floor below the filter. In this fashion, the operators proceeded along the press until all of the residue had been removed from the frames. After a quick washing of the filter press, the grid plates were repapered and the filter press was reset to await the next batch of solution from the purification tank.

The filtrate from the first purification operation was discharged into the second purification tank where heat, agitation, and zinc dust additions resulted in precipitation of the majority of the cadmium present, along with cobalt, nickel, and other trace metals. A second Shriver press was used to filter the tank's contents, and the residue from that filtration was also collected on the floor below. The filtrate was discharged to a third agitator tank where zinc dust was again added to precipitate trace cadmium. The purified zinc sulphate solution from the third filtration was piped to check tanks for analysis of purity before being gravity fed to neutral storage tanks on the Tank Floor of the Main Building. The Launder Bridge connected the northern end of this floor with the Lower Plant, where preparation of cell feed electrolyte took place.

The pregnant zinc sulfate solution that was gravity fed from neutral storage by a launder over the bridge that spanned the gap between Upper and Lower Plants entered the balance tank. This 42 ft. diameter by 7.5 ft deep lead-lined wood stave tank was situated in the Electrolytic Department Manganese Room north of the building that contained the Cell Room. It received cell circuit return electrolyte that had been depleted of its zinc content (through electrodeposition on cathodes), at the same time that its H_2SO_4 content had been enriched to approximately 28% (by the regeneration of sulfuric acid during electrolysis). When the tank had been filled to a certain level, a valve on the neutral storage tank was opened and neutral solution was admitted to the balance tank to provide a fresh supply of zinc for electroplating, and to dilute acid strength "from about 28% to 22%, which [was] the normal range of electrolysis."¹¹³ The electrolyte that then contained a proper balance of zinc sulphate and sulfuric acid was pumped up into the cooling cells before being introduced into the electrolytic cell circuits.

Woolf and Tainton had designed and tested cooling systems at the North Mill during the 1925-27 pilot plant work.¹¹⁴ The system that they incorporated into Zinc Plant operations relied upon the use of "several long boxes about 4 ft. square, down which the [electrolytic] solution flow[ed]."¹¹⁵ A counter-current flow of cooling water circulated through lead coils placed across the boxes. This cooled the electrolyte from 45°C. down to 40°C., a temperature that was necessary for efficient zinc electrolysis.¹¹⁶ The cooling cells were above and immediately north of the electrolytic cell circuits. A method for preventing the buildup of deposits on the coils' cold surface was part of the cooling system design. Lead grids were placed between coils, and the boxes were connected to the cell circuits' 8000 ampere electric current for brief intervals. The lead grids and coils acted as anodes and cathodes, with a thin layer of zinc being plated on the coils. As the zinc went "back into solution [it] evolve[d] hydrogen and [broke] off any adhering crust or scale, so keeping the coils at their maximum heat-conducting efficiency."¹¹⁷

Cooled electrolyte was distributed to the electrolytic cells by means of feed launders directly above the two 150-cell circuits. Each circuit was composed of two 75-cell rows. The cells of the completed Zinc Plant were 7 ft. long and 4 ft. deep. They were a little less than 3 ft. wide.¹¹⁸ Solution entered the cell through a hard rubber pipe over the center of each cell, overflowing through discharge pipes on each end of the cell. Within each cell, the electrolyte circulated through an arrangement of 20 anodes and 10 cathodes. Each cathode was arranged with two anodes (one on each side of the cathode). Cathodes were inserted into grooved wooden guides, held in position by internal cell frames. The guides also served as spacers for the anodes. A copper busbar transferred current between cells. A copper spring clip bolted to the busbar at the location of each cathode established a connection between the cathode header bar and the busbar. Anode header bars were held in contact with the busbar by a rigid metal clip bolted to the busbar.

The current that passed through the cells plated the zinc in the solution onto the aluminum cathodes, while H_2SO_4 regenerated as a result of the electrolytic process. Spent electrolyte overflowed into a discharge pipe at each end of the cell which directed the flow to a sump. During the course of electrodeposition, manganese dioxide precipitated out of solution and was carried with the spent electrolyte into the sumps. It was discharged along with the electrolyte into a Dorr thickener tank in the Manganese Room, where the manganese dioxide was recovered as a sludge. Due to its low lead content, Tainton noted that it was saleable as "an oxidizer in batteries," thus it was "filtered, washed, and prepared for market."¹¹⁹ Overflow from the thickener tank supplied the balance tank. At the end of a 24-hour period, more neutral solution was introduced into the balance tank and fed into the cell circuits.

"Antisell-type hard lead pumps" continued to circulate the

solution "so that the entire volume passe[d] around the circuit every one-and-a-half hours."¹²⁰ The reagents that had been tested at the North Mill were added to the cooled electrolyte before it entered the circuit. For every ton of solution, 3.5 lbs. of silicic acid (SiO_2) and an emulsion containing 1.5 lbs. gum arabic and .75 lbs. cresylic acid (per ton of solution) were fed into the electrolyte.¹²¹

At the time that a fresh batch of electrolyte was introduced to the electrolytic cell circuit, spent electrolyte was withdrawn from the cell room sump and held in a pumpover tank in the Manganese Room, prior to being pumped to the return electrolyte storage tank on the Tank Floor of the Upper Plant. It was held there until spent electrolyte (H_2SO_4) was needed for Leaching operations.

The cathodes were pulled from the cells after zinc had been allowed to plate over an eight to twelve hour period (later standardized at eight hours on the 10,000 ampere cell lines). As the plated cathode was withdrawn and allowed to drip, a clean cathode was inserted in its place. The operation was conducted by hand from a platform gangway above the cells. A hooked rod was used to raise the cathode above the solution. After it had drained, another worker removed the cathode to a hand-truck for conveyance into the Stripping Room in the Melting Department. Stripping was accomplished by tapping the zinc "sheet with a bar [and] passing a stripping knife under one of the edges" of the zinc sheet, which enabled the stripper to skin first one side of the cathode, then the other.¹²²

Power was supplied to the original Cell Room by means of two 4000 kilowatt capacity Motor Generator Sets. Each one supplied a direct current of 8000 amperes at 500 volts to the circuits. Tainton remarked on the debate surrounding the choice of these in his 1928 Engineering & Mining Journal article: "The general consensus of opinion among the electrical engineers favored the installation of rotary converters on account of their higher conversion efficiency. The metallurgists, on the other hand, expressed a preference for motor-generator sets because of their greater flexibility and freedom from interruption caused by line disturbances."¹²³

The Melting and Casting Department produced the finished Special High Grade zinc castings. It occupied a building on the eastern side of the Lower Plant, across the railroad tracks from the Residue Department of the Upper Plant. Stripped zinc was piled in 700-800 lb. bundles on hand trucks and weighed before being transferred to the oil-fired reverberatory furnace that produced the molten metal. From the furnace ladling wells, pure zinc was ladled out and cast by hand into 60 lb. slabs. Dross formed in the main bath area of the furnace, which was separated by a wall from the ladling wells. Submerged ports in the separating wall permitted molten zinc to flow from the main bath area into the ladling wells. The dross was "skimmed off at intervals, run thru

[sic] tumbling drums to remove metallics and stored for shipment."¹²⁴

The zinc dust that was used in Purification was blown from remelted zinc prills obtained from the dross treatment reverberatory and cull slabs. Molten zinc was poured into a heated crucible with a ceramic plug. A small hole in the plug allowed the zinc to leak out, where it fell through an air jet that atomized it, solidified it into fine particles, and blew it into a storage bin. A pneumatic conveying system was used to transfer the zinc dust from the bin to a hopper adjacent to the northern side of the Purification Department. For the movement of other supplies to the Upper Plant area, a rampway was built along the southern side of the Upper Plant. A small hoist was then used to draw materials and equipment up the slope to the required location.

G. Technological Change and Plant Additions 1929-81

In 1929, a Cadmium Plant was added to the plant process facilities.¹²⁵ Metallic cadmium, and copper and cobalt residues were produced there from the formerly stockpiled, but unprocessed, residue of Purification. It was built immediately north of the Purification division of the Upper Plant, on the level of residue collection from the Shriver press filtering process. In all respects, except for roasting, its operating processes were similar to those of the Zinc Plant.¹²⁶

The residue was transported from the floor below the Shriver presses into a storage bin within the Cadmium Plant. This bin supplied feed to a 4 1/2 ft. by 16 in. diameter pebble mill that was lined with silex blocks to protect it from abrasion and corrosion. Residue was conveyed to the pebble mill's feed hopper and repulped with mull (wash) water from the Shriver presses. The mill pulp was gravity fed through a trommel into a 15 ft. diameter by 11 ft. deep wood stave leach tank, that was heated by hard (antimonial) lead steam coils. The trommel screened out any pebbles or other large material. A controlled combination of Zinc Plant electrolyte and a dilute acid solution was added to the lead-lined leach tank, and the mixture was agitated. Cadmium and other trace metals went into solution, leaving a cement copper residue in the pulp. The pulp was filtered through a bronze Shriver plate and frame press, similar to those used in Purification, to capture the cement copper. This residue contained 60-70% copper. After the filtrate had been discharged into a 14 ft. diameter by 8 ft. 8 in. deep purification tank with steam coils, the residue was removed from the filter and held for shipment to a copper smelter.¹²⁷

More electrolyte was added to the cadmium/cobalt solution in the purification tank to maintain proper acidity, and the tank was agitated while zinc dust was introduced to precipitate the cadmium in sponge form. The tank's contents were then pumped to a second Shriver press for capture of the cadmium sponge. The filtrate still contained a small portion of cobalt, and this was again

treated in an agitator tank with zinc dust to precipitate the cobalt. One more pass through the #2 Shriver press separated the cobalt residue from the now nearly barren solution, which was pumped back to the Zinc Plant for recovery of zinc. The small quantity of cobalt filter cake was stored "for possible future re-treatment."¹²⁸

The cadmium sponge was transferred from the filter press to a steam plate located in a storage bin, where it was partially oxidized. When a sufficient amount of cadmium sponge had accumulated, it was introduced into an 8 1/2 ft. diameter by 8+ ft. deep re-solution tank and agitated with spent electrolyte from the Cadmium Plant's electrolytic cells to produce a neutral solution. The neutral solution was passed through a small Shriver press (31 frames and 30 grid plates, 18 in. square) to separate excess sponge from the cadmium-rich solution. This final press residue was readmitted to the pebble mill at the beginning of the plant circuit.¹²⁹

Pure cadmium electrolyte was then ready for introduction into the 12-cell electrolytic system. Electrolysis here differed from the Zinc Plant Cell Room in that a low current density (10 amperes per sq.ft.) was used, and glue was the only addition agent.¹³⁰ Each 75 in. long by 43 in. wide by 30 in. deep cell contained 32 anodes and 16 cathodes, connected by busbars. Cathodes were pulled at 24-hour intervals, half of the cathodes being pulled at a time, with the remainder maintaining the circuit.¹³¹ After the first cathodes had been replaced, the second half of the cathodes were pulled and stripped of the thin sheets of cadmium. These were rolled into a bundle for weighing, which was then dropped through a hole in the floor and onto a table on the casting floor.

The cadmium bundles were melted under a cover of molten caustic soda (to contain the cadmium fume within the caustic layer) in an electrically heated cast-iron pot, and the molten metal was drawn off through a spout into hand ladles for casting in molds that produced either balls or pencils.¹³² After sprues had been removed from the molded cadmium and returned to the pot for remelting, the product was boxed up in 100 lb. lots for marketing.

Melting pot dross was dissolved with fused caustic soda in a trommel that was partially submerged in a 5 ft. 6 in. diameter by 4 ft. 6 in. deep treating tank. Cadmium solids were filtered and readmitted to the cell circuit, and the caustic solution was recycled to the re-solution tank.

The effect of the Great Depression on American Industry is well known, and it was reflected in the scaled down operations of the Sullivan Zinc Plant during that time period. Demand for slab zinc slackened, and plant output was curtailed to one-quarter of its capacity in 1930, but improvement in the metals market during the 1934-36 period allowed Sullivan to increase production, which was abetted by "orebodies of high zinc content [that] had been developed in the Bunker Hill Mine."¹³³ In 1937, the Sullivan

Mining Company decided to expand the Zinc Plant, both in terms of physical plant and operating equipment.

The operation that had begun in 1928 utilized five Wedge roasters, three leach tanks, six Burt filters, three purification tanks, and three Shriver presses to supply two 150-cell electrolytic circuits with purified zinc sulphate.¹³⁴ The Zinc Plant's fifty-ton per day output was cast from one 15 ft. by 28 ft. oil-fired reverberatory furnace. The 1937 expansion would add another Wedge roaster, three more leach tanks, three Burt filters, and two additional purification tanks to the Upper Plant. With the installation of larger diameter pipelines and increased pump pressure, only one more Shriver press was needed.¹³⁵ A third 160 cell circuit was added to the Cell Room, and a second reverberatory furnace was put into operation in Melting and Casting. The result was a plant capacity of 120-tons of slab zinc per day.

To house the new equipment, modifications were made to the original Zinc Plant structures: A Surge Tank section was added onto the southern end of the Leach Floor; the Filter Floor required expansion to the south for the new Burt filters; in the Electrolytic Department, new construction increased the size of the Manganese, Cell, and Generator Rooms to the west; an Air Conditioner Wing was attached to the southern side of the new Generator Room; and a Zinc Slab Storage Building was built south of the Stripping Room to warehouse the increased output from Melting & Casting.¹³⁶ Auxiliary facilities were expanded or newly constructed, too: The Plant Dry, or Changehouse, had a section added onto the northern side; a new Maintenance Office and Garage was built to the east of the Dry; a new Compressor House was erected north of and adjacent to the Boiler House; and, farther south up Government Gulch, a Framing Shed and Carpenter/Lead Shop were constructed.¹³⁷ Minneapolis Steel, one of the original Zinc Plant contractors, supplied the steel for the additions, which were erected by Sullivan Mining Company crews.

A decline in the metal markets in 1938 forced the Sullivan Mining Co. to reduce plant output to one-third of capacity.¹³⁸ However, the events that were to culminate in World War II soon generated an increased demand for zinc and cadmium at the same time that it deprived the Zinc Plant of badly needed labor. Some relief was provided by hiring Midwestern farmers (dislocated by the "Dust Bowl" conditions of the Great Depression), obtaining soldiers on furlough for plant work, and the hiring of women.¹³⁹ The Zinc Plant's version of "Rosie the Riveter" was employed in many plant operations, including the Burt filter operator pictured in Photograph ID-28-4. High school and college students were also an important part of the war-era work force, providing the operation with much needed help during weekends and vacation periods. With the end of war-induced labor shortages, the operating role of women declined, as returning servicemen re-entered work at the Zinc Plant.

The Sullivan Mining Co. planned and executed another expansion

of the Zinc Plant in the years 1947-48. The addition of more process equipment in Roasting and Leach/Purification, and the incorporation of a fourth circuit of 160 cells in the Electrolytic division boosted output to 160 tons per day.¹⁴⁰ Additional Wedge roasters were installed, bringing the number of calcine producing units to ten. Kansas City Steel Company furnished the steel, and Sullivan Mining Company supplied the construction crew for building modifications attendant to this expansion. They erected additions that included: housing for Wedge roasters on the northern end of Roasting, expansion of the Filter Floor on the north and south, additional space on the northern end of the Tank Floor, a northward extension of the Manganese Room, a unit to house the new cells (west of the original Cell Room and adjacent to the 1937 expansion on its south), and a second Air Conditioner Wing west of the Generator Room.¹⁴¹ Small additions to the Cadmium Plant were placed on its northern and southern ends, and the Dry had a third section built on the south.

A twenty-year period of expansion and physical plant change was ushered in during the early fifties. A major element of this was the decision to convert a waste product (sulfur dioxide gas) into a salable byproduct (sulfuric acid). Bunker Hill had been approached by a metallurgist, Harmon E. Keyes, twenty years previously, regarding "a cheap method for fixation of sulphur dioxide from roaster and smelter gases...which...produces dilute sulphuric acid."¹⁴² Keyes had worked as a chemist for Tainton, both at the Martinez plant and the North Mill pilot plant. In the years following 1924, he had been employed as a metallurgist in the Southwest, with particular involvement in treatment of SO₂ emissions. Although Keyes knew that a patent governing sulfuric acid production had been established by A.M. Clark, a British chemist, in 1888, Keyes was trying to patent his own modifications of Clark's method, and he sought Bunker Hill's participation in developing these modifications.¹⁴³ Keyes received a reply from R.G. Hall, a consulting engineer employed by Frederick Bradley, which put Bunker Hill's priorities in the context of the times: "At the Bunker Hill smelters [sic], however, we are inclined to believe that the time when such an installation may be made with any hope of commercial success is probably far in the future. At present in common with all the smelters of the West, they are more concerned with keeping alive some small part of the present installation, and could not be prevailed upon to discuss any additional capital expenditures."¹⁴⁴ Hall's apt prediction of the timing for a sulfuric acid plant was tied to better economic times. The post-war economic boom in the United States and a demand for sulfuric acid led to a Sullivan Mining Company decision to engage the New York engineering firm of Singmaster and Breyer in 1950 to perform engineering and design work related to the installation of a Monsanto Sulfuric Acid Plant and the necessary attendant revisions to the existing plant. The contract for installation of

these facilities went to the Stearns-Rogers Company of Denver, Colorado, and these new process facilities were ready for initial operations in 1954.¹⁴⁵

To provide the Acid Plant with a gas stream suitably rich in sulfur dioxide, a change in roasting equipment was required. Eight of the old Wedge roasters (which produced a gas that was approximately 3% SO₂) were replaced with four flash roasters (capable of producing 7% SO₂ in the gas). The original Wedge roasters were paired in succession in their process area (see Photograph ID-28-5), the rabble arms of the eight hearths turning on a central shaft connected by a bull gear to the roaster drives underneath them (as shown in Photograph ID-28-6). The flash roasters and their waste heat boilers were placed in former Wedge roaster locations and put into operation in 1951. Two Wedge roasters were retained, and one of these was used for dechloridizing melting furnace dross in later years.¹⁴⁶

As part of the construction related to the flash roasters, the Roaster Floor was extended to the north in 1951, and additional Concentrate Storage bins were built to the east of Roasting in 1952. Earlier, in 1950, the Surge Tank section next to Leaching had been extended to the south, the Filter Floor received a southern extension, two more thickener tanks were built adjacent to the existing tanks south of the Upper Plant, the Residue Floor had been doubled in size by a northern addition, and a new Warehouse was erected to the south of the original Warehouse).¹⁴⁷ The Compressor House received a small addition in 1952. Kansas City Steel and Union Iron Works of Spokane, Washington supplied steel and machinery related to these construction activities.

Delivery of concentrates from the new Concentrate Storage bins to the feed distribution conveyor belt was accomplished with Eimco loaders, which allowed "a blending of various concentrates for roaster feed."¹⁴⁸ This conveyor belt was capable of delivering concentrates to the Pretreatment Plant (built in 1953), the Concentrate Dryer Building (abutting Pretreatment), or to the roaster feed bin delivery system.

Concentrates that didn't require pretreatment had their moisture content reduced in the Ruggles-Coles dryer from 10-11% to 3.5-4%.¹⁴⁹ The partially dried concentrates were conveyed by a system of feed screw, bucket elevator, and belt to dry concentrate storage bins. These, by means of a similar conveyance system (with the addition of trippers), supplied the flash roasters' concentrate feed bins. A belt feeder below the roaster feed bin delivered concentrates to the flash roaster.

The flash roasters had the same 25 ft. diameter as the Wedges, with a vertical height of 32.25 feet. Within each of them were two top drying hearths, a combustion chamber slightly over 19 ft. high, and two lower hearths. Concentrates that entered the top hearth were raked by rabble arms over the drop hole that led to the second hearth. From that hearth, they were discharged to a 4 ft. diameter by 7 ft. Hardinge ball mill located on the bottom floor of the

Roasters. Forged steel grinding balls pulverized the concentrates, which were air-swept from the mill discharge into a Hardinge air classifier. The undersize was conveyed to an 8.3 ft diameter cyclone in the air stream, which supplied the dry concentrate feed bin above the roaster. Oversize material from classification was returned to the ball mill. A belt feeder dropped concentrates from the dry feed bin into the burner feed chamber, where air supplied by a firing fan blew the fine concentrates into the flash roaster. The flash chamber had a temperature "in excess of 900° Centigrade," which ignited the sulfur in the air-suspended concentrate particles.¹⁵⁰ This resulted in the formation of a zinc oxide calcine and sulfur dioxide gas. The calcined material settled onto the collection hearth, where it was rabbled to the next hearth and discharged by means of water-cooled screw conveyors to the Jacoby conveying system that fed the sizing and conveying system, which supplied the calcine bins. Any oversize material was returned to the ball mill.

The gases from combustion were passed from the combustion chamber through a waste heat boiler. The steam generated there was used to power the Acid Plant turbine, which, in turn, powered the fan which conveyed gases through cyclones, a balloon flue, and a dry Cottrell that had been built on the northern end of the extended Roaster Floor. Dusts that were eliminated from the gas stream by this system were returned to the flash roaster. From there, gases were drawn into a Peabody scrubber, and mist precipitators by suction from the Acid Plant turbine.

The #1 Acid Plant and its related process equipment (Peabody scrubber, mist precipitators) were erected in 1953-54. It was a standard sulfuric acid manufacturing plant, as designed by the Monsanto Corporation. The Peabody scrubber and mist precipitators were situated to the immediate north of the dry Cottrell. The Acid Plant was built to the east of the Roaster Department. A Rectifier Building was also built in 1953, in the area between the Pretreatment Plant and the Peabody scrubber.

The manufacture of sulfuric acid from formerly waste gas involved the purification of the sulfur dioxide gas, conversion of the sulfur dioxide gas to sulfur trioxide gas, and absorption of the SO_3 gas into sulfuric acid. Gas that was approximately 7+% SO_2 came through the dry Cottrell treater and flowed through the Peabody scrubber, where counter-current water sprays cooled it from 485° Fahrenheit to 95° F., at the same time removing part of any remaining entrained solids. Cleaned gas from the scrubber entered two mist precipitators, where electrostatic precipitation captured "most of the remaining particles of acid mist, metallic fume, and dust."¹⁵¹ Purified gas exited the mist precipitators and was drawn by the suction from the Acid Plant's blower through a lead duct to a drying tower within the Acid Plant proper. Once there, it flowed "counter current to 93% or stronger acid" which absorbed the remaining water.¹⁵² The pure SO_3 gas was then ready for the conversion process.

The Monsanto "3 Pass" converter received the blower-driven gas after it had passed through heat exchangers. It was a 30 ft. high by 20 ft. 9 in. diameter Insulkote covered steel chamber, accessed by 4 ft. diameter steel ducts. A vanadium pentoxide (V_2O_5) catalyst within the converter accelerated the chemical reaction between SO_2 and O_2 that formed SO_3 . A 29 ft. high preheater was used to "raise the temperature of the catalyst [to the point] at which conversion of SO_2 to SO_3 will occur."¹⁵³

The SO_2 gas from the drying tower was heated to 820° Fahrenheit when it flowed through the heat exchangers in series. These were identified as cold, intermediate, and hot. The cold heat exchanger was 32 feet high by 9.5 ft inside diameter, the intermediate was 30 ft. high by 8 ft. inside diameter, and the hot was 30 ft. high by 9.5 ft inside diameter. Within each of these steel units were tubes (1560 in the cold and hot, 1000 in the intermediate). After leaving the heat exchangers, the gas passed through the top layer of the converter, returning to the hot heat exchanger. It then made a second pass through the converter, returning to the intermediate heat exchanger. The third pass through the converter was followed by a return to the cold heat exchanger. During each pass through the converter, SO_2 was converted into SO_3 by the catalyst assisted reaction between SO_2 and O_2 . SO_3 traveled through the tubes, and SO_2 flowed around the tubes. The heat exchangers served to minimize variation in the temperature at which the reaction occurred. From the initial heat exchanger obtained 820° F. temperature, the gas temperature elevated to 1020-1100° F. during the first pass reaction. Its reintroduction to the hot heat exchanger cooled the gas to 850° F. The intermediate heat exchanger received 900-925° F. gas from the second pass and cooled it to 800° F., and the cold heat exchanger cooled 800° F. gas down to 437° F. The reaction was complete then, and the gas was pushed by the blower into the SO_3 cooler, which lowered the gas temperature to 250-300° F., the ideal temperature range for gas absorption.

The 20.25 foot inside diameter by 30 ft. high absorbing tower was of the same dimensions as the drying tower, and it was linked to it by a cross-flow of acid. A quantity of absorbing acid was transferred to the drying tower pump tank "to maintain a constant acid concentration at a minimum of 93.19%."¹⁵⁴ This was needed because the 93% acid in the drying circuit was diluted by the water absorbed from the incoming gas. Drying tower acid flowed back to the absorbing tower pump tank to "maintain a constant tank level and proper acid concentration" as it received and absorbed SO_3 from the SO_3 cooler.¹⁵⁵ During absorption, acid was withdrawn from the absorbing tower pump tank, and dilution water was added to maintain the acid concentration, which was strengthened by the absorption of SO_3 . Acid leaving the absorbing process was water cooled in National Radiator acid coolers. Cooled acid was piped to one of four 2000-ton capacity storage tanks placed to the north of the Zinc Plant, along the railroad line. This area was also the

loading site, where acid was transferred to rail tank cars and truck tank trailers for shipment. The Acid Plant at the Sullivan was similar to acid plants in other parts of the world, where conversion of byproduct SO_2 to H_2SO_4 provided smelters and refineries with a marketable product from formerly waste gas.

During the Acid Plant construction in 1953, the Zinc Plant underwent further structural modification with the addition of a manganese dioxide ball mill to the southern end of the Roaster Floor and the building of a small section onto the northern end of the Leach Floor.

Concentrates that did require pretreating were conveyed from concentrate storage to the Pretreatment Plant, or Pend Oreille Building. This facility was located at the level of the Roaster division, to the immediate north of that process area. It was built specifically for treatment of ore concentrates produced in the Pend Oreille Mining District, near Metaline, Washington. These concentrates contained magnesium carbonate, an impurity that was removed at the Pretreatment Plant. The pretreatment method developed by Walter Schmittroth of the Sullivan Mining Company for Pend Oreille ore was a batch process.¹⁵⁶ A separate facility was required because magnesium was higher on the electromotive scale than zinc, and couldn't be replaced by zinc dust in the oxidation reduction reaction that precipitated copper, cobalt, and cadmium in Purification.¹⁵⁷

A 9 ft. by 10 ft feeder bin received forty tons of concentrate from storage, which was sampled. The sample was tested with sulfuric acid "to determine acid consumption of the concentrate and from this value the acid to be added...is calculated."¹⁵⁸ At that point, the feeder was started, and 33 tons of concentrates were fed into a 6 ft. by 48 in. Hardinge conical ball mill. Process water was added and a slurry was formed. The measure of concentrates was controlled by a weightometer, and the addition of water was regulated by a rotameter. A trommel at the discharge screened out oversize. The ball mill slurry was pumped to one of four 20 foot diameter by 13 foot deep wood stave leach agitator tanks.

Concentrated sulfuric acid was drawn from a storage tank and mixed with water in two 10 ft. diameter by 5 ft. lead-lined diluting tanks to produce 10% H_2SO_4 . The acid was gradually introduced into the leach tank during a one hour period, with the use of spray water "during and after acid addition to control froth."¹⁵⁹ The last water sprayed into the tank brought the leach up to agitation volumes. The timing for this and the succeeding digestion of magnesium in the leach tank was governed by factors like settling rates, agitation speed, and acid strength, all of which had been carefully observed by Schmittroth and the Zinc Plant staff in developing the process.

Over an approximate four hour period, the leach was agitated and sampled at hourly intervals. Sampling measured the acid level, which was modified by the addition of more acid, if needed. At the end of the time, agitation was slowed, and settling of the pulp

occurred. When settling was complete, a siphon was inserted into the tank to decant and discharge the solution and the magnesium sulphate it then contained into zinc flotation cells in the Pretreatment Plant. It was carefully drawn off to avoid extraction of the concentrate material that had settled. When siphoning was completed, the agitator was speeded up, water added, and the mixture repulped. Following resettling, the solution was decanted and discharged again, at a faster rate, following which the pulp was remixed with the agitator. If it tested neutral at that point, the pulp was ready for filtering; acidity indicated further agitation, settling, and decanting was needed to completely remove the magnesium.

The pulp was filtered on an 8 ft. diameter by 12 ft. Reeves drum filter. It was kept in agitation in a holding tank and continually fed to the filter reservoir. The cake from filtering was dried and stored for eventual introduction into Roasting. The filtrate was pumped into the zinc flotation cells, joining the leach decant, where air and a frothing reagent were used to produce a zinc concentrate that accumulated in a sump. At biweekly intervals, the flotation concentrate was pumped back into the Pretreatment leach tanks.

The Zinc Plant assumed a name change on the last day of 1955, when the Sullivan Mining Co. was dissolved. From this time forward, the operation was known as The Bunker Hill Zinc Plant. Earlier in that same year, the original two 150-cell electrolytic circuits were modified by the addition of ten cells on the north end of each circuit to make them equal in capacity and configuration to the two newer 160-cell circuits. A new Lead Shop was also constructed in 1955, adjacent to the Carpenter Shop at its southeast corner.

Two 6000 KW Ignitron mercury arc rectifiers had been added to the Generator Room in 1950. These units joined the motor generator sets, supplying 10,000 amperes of D.C. power to the cell circuits. They were simpler and more efficient in operation, representative of current state-of-the-art power production.

In 1956, a planned expansion of Cell Room production called for another alteration of the Lower Plant. Concrete foundations were installed and the Cell Room Building was extended to the west. This new electrolytic addition would be capable of housing two more 160-cell circuits. A fifth circuit was completed in 1957, bringing the total number of cells up to 800. The Zinc Plant was then capable of producing 210 tons of slab zinc per day. Concurrent with the Cell Room expansion, Lower Plant additions were made to the Generator Room and Manganese Room on the west, and Melting & Casting was extended to the north. In that same year, the Dressing Plant and a new Zinc Dust Building were built to the north of Melting and Casting. Also in 1956, an Electrical Distribution & Control Center was erected adjacent to the northern edge of the Manganese Room, and a new Cooling Tower was constructed to the

north of the Lower Plant. The tower replaced the old system of cooling cells fitted with lead coils carrying a counter-current flow of cooling water. Electrolyte was pumped up into the Cooling Tower, where it flowed through packing, counter-current to cooling air moving up through the tower. Heat from the falling solution was transferred to the rising air. The cooled electrolyte collected in a sump and was pumped into the cell distribution launder, which redistributed electrolyte into the cell feed launders.

Upper Plant additions in the 1956-57 time period were: a final extension of the Leach Floor to the north (additional Burt filtrate storage), a westward expansion of the dry Cottrell Building abutting the Roaster Floor, a northern addition to the Purification Department (with a new Zinc Dust Tower adjoining that), and a Tank Floor extension to the north. Kansas City Steel again supplied the steel on these and the Lower Plant additions, which were all constructed by Sullivan Mining Company crews.

With the expansion of the Generator Room, more air conditioners were installed, south and outside of the power generation facility. The Zinc Plant Dry assumed its final shape at this time, with additions being constructed on its eastern and southern portions.

The 1956 expansion included construction of the Anode Cleaning Building, to the West of the Cell Room. A covered trestle joined these two facilities. The Anode Building housed an improved maintenance arrangement for the lead-silver alloy anodes used in electrolysis. They required removal at eight day intervals from the cells for cleaning of the manganese sludge that would build up on them. O.J. Jasberg, the Plant Engineer, designed an anode cleaning machine, which continuously conveyed dirty anodes through a brushing, washing, and flattening system, preparatory to return to the cell circuits. Before the advent of the Anode Building and its machinery, anodes had been scrubbed and washed on open-air platforms to the west of the Cell Room, and a small, adjacent shed had contained a press for flattening cleaned anodes.

The anodes were cleaned down to an unpolished appearance, then aged for a 24-hour period to allow surface oxidation. The need for this aging process was discovered during the 1925 pilot plant work that developed the lead-silver alloy anode. Ehrlinger observed that "for the first twenty-four hours, it was almost impossible to get any deposits with the purest of solutions. The anodes had to go through this breaking in period before they would function properly...it was quite evident that the presence of some free silver on the anode surface was what was causing us all of the starting trouble."¹⁶⁰ Anode Manufacturing was appended to the south end of the Anode Building in 1963. The manufacture of anodes and cathode header bars, as required, took place here. In the process of constructing the Anode Cleaning Building, the old Gatehouse was demolished, and a new one was built at the Zinc Plant's northwest corner in 1957.

Beginning in 1957, the Melting and Casting division of the Lower Plant was subjected to changes that resulted in expansion and diversification of the Zinc Plant's line of finished products. The initial changes centered on new zinc melting and casting equipment. Design work on an electrical induction furnace, straight-line casting machine, and the foundations for them had been performed in 1956-57 by Peter M. Jasberg of the Zinc Plant engineering staff. Upon its completion, an Ajax 800 KW electrical induction furnace was purchased and installed in the Melting and Casting Department in the spring of 1957. Its output supplied a Sheppard straight-line casting machine that turned out 60-lb. slabs. The Ajax furnace output was later adapted to feed a stationary mold line, capable of producing 2400-lb. zinc blocks.¹⁶¹

Alloy production became the new direction that was emphasized. Equipment was added to give the Zinc Plant the capability of manufacturing a broad variety of zinc alloys (combinations of zinc with copper, magnesium, and/or aluminum) Design work for the alloying equipment immediately followed the installation of the Ajax and Sheppard units. In 1958, an Ajax 200 KW alloy induction furnace, reverberatory melting furnace and an alloy casting wheel were installed and production of alloys began. Molten zinc from the 800 KW induction furnace was pumped into the 200 KW induction furnace. It was agitated and mixed with alloying material that had been melted in the alloy reverberatory furnace, and then laundered into the 200 KW induction furnace. When the appropriate alloy mixture was achieved, the furnace's output was cast in molds on the alloy casting wheel.

Another step in product diversification was taken when Melting & Casting began production of cathodic protection zinc anodes in 1958. These were cast from pure zinc and contained a steel bar for attaching them to the material that required corrosion protection. They were useful in underwater applications, pipelines, and other facilities. The zinc went into solution instead of the steel structural materials as corrosion took place.¹⁶²

The decade of the sixties brought changes, both in physical plant additions and in process alterations. Its opening year, 1960, was marked by two events of significance to the Zinc Plant. Wallace Woolf retired at age seventy, closing out a forty-two year career with the Bunker Hill and Sullivan Companies. He served as interim president of the Bunker Hill Company following the November, 1959 death of John Bradley, president since the mid-fifties. Woolf began his service with Bunker Hill during the long presidency of Frederick W. Bradley, the father of John Bradley.

In May of 1960, the Zinc Plant was affected by a labor strike called by the United Mine-Mill Workers. The labor stoppage lasted from May 5, 1960 to December 21, 1960. It was the most serious labor disturbance ever to involve the Zinc Plant, and Bunker Hill's worst since the 1949 strike, which was of shorter duration. The

strike came to an end only after Mine-Mill had been decertified by the workers that it represented, and a new union, the Northwest Metal Workers, had been formed to negotiate a labor agreement. The long nature of this strike resulted in maintenance problems that hampered a return to full production.

In the first half of the decade, a number of construction projects were completed at the Zinc Plant. A Dressing Plant extension to the east took place in 1960, followed by a Dressing Plant addition and Dross Storage bin construction to the north of the existing plant in 1962. Also in 1962, a sixth 160-cell circuit was put in operation on the west half of the 1956 Cell Room extension. This increased the Zinc Plant output to 260 tons of slab zinc per day. The Manganese Room had received a small addition on its northern end in 1961, in the area over the Cooling Tower sump tank. The Warehouse had two additions appended to it in the mid-sixties. An oxygen/hydrogen storage area and acetylene generation and distribution facility were housed in the 1964 addition that was built onto the southeast corner of the Warehouse. The generated acetylene was piped to various locations throughout the Zinc Plant for use in welding and cutting torches. In 1965, a Pipe Shop was added onto the south side of the 1964 construction.

Utilization of a bin in Roasting for receipt of dross was part of a 1966 change in the method of handling the dross that was skimmed from the Melting Room furnaces. Dross had formerly been emptied into a drum that was heated to render the entrained zinc prills molten. Zinc dust was blown from the prills, and the recovered zinc dross had been stored, prior to resale. Beginning in 1966, a pneumatic conveying system was put in use, in conjunction with a dross mixer (similar to a cement mixer). The skimmed dross was fed into the mixer, which was air-swept, causing the dross to be picked up by the air stream as a dust. Escaping air entered a baghouse for capture of trace dust, which joined dross that was blown into a bin. A pneumatic conveying system moved dross from the storage bin through an 800-foot line, discharging at the dross bin in Roasting. The bin supplied dross to a Wedge roaster, which was used to dechloridize the material from the dressing operation. Chlorine gas that came off the roaster was treated in a wet scrubber. The zinc oxide material was then ready for retreatment in Leaching.

A secondary pneumatic conveying system was installed in Purification in 1967. Zinc dust was conveyed from the Zinc Dust Building by the primary pneumatic system to the Zinc Dust Tower. The secondary pneumatic system distributed dust from the tower to individual tanks on the Purification Floor. Prior to this, zinc dust was manually removed from the zinc dust bin and distributed to the purification tanks.

A major expansion and modification of plant facilities, that had been announced in late-1965, took place in 1965-67. Kaiser Engineers, of San Francisco, had contracted for the installation of a second Acid Plant, a new flash roaster, and concentrate handling

facilities.¹⁶³ As part of this, the Zinc Plant's Research and Analytical Laboratories would be removed, and their functions would be combined with laboratories from the Lead Smelter and the Bunker Hill Mine at a new Central Research & Analytical Laboratory located at the mouth of Government Gulch.

A Chemico Acid Plant was built to the immediate east of the 300 ton per day Monsanto Acid Plant. It came on stream in 1967, with a 350-ton per day capacity. Except for the increased capacity, "processing in the two plants...[was] almost identical."¹⁶⁴

The #5 Roaster occupied a new building erected partly over the site of the former Research and Analytical Laboratories. It used the same process as the 125-ton per day flash roasters installed in 1952, but its output was substantially greater, the single roasting unit being capable of producing 350-tons per day. This sizable new facility contained a baghouse for the capture of dusts in the roaster gases. The #5 Roaster Building was situated south of the Upper Plant Main Building and east of the Warehouse/Pipe Shop.

Concentrate Handling occupied a large structure that was also south of the Main Building and slightly southeast of the #5 Roaster. Zinc concentrates from a variety of sources were received and segregated by type in the fourteen 1000-ton storage bins contained in the facility. In addition, Pend Oreille District concentrates that underwent leaching in the Pretreatment Plant were pumped over to Concentrate Handling after completion of the Pretreatment leaching operations. These concentrates accumulated in a thickener tank, were reduced to a filter cake on a drum filter, dried, and added to the other processed concentrates in a silo outside of the #5 Roaster. A conveying system carried concentrates from the silo to the #5 flash roaster. The filtrate from the drum filter was treated in flotation cells to produce a concentrate that was reintroduced into the slurry tank. Use of Concentrate Handling's slurry tank, filter, dryer, and flotation cells supplanted similar equipment that had been used at the Pretreatment Plant.

A calcine storage silo received the output of the #5 Roaster. It was located adjacent to the dry concentrate silo in the space between Concentrate Handling and the #5 Roaster. The calcine was conveyed from here to Leaching, joining the calcined material from the older Roasting plant.

In 1966-67 a new, packless, cooling tower was erected north of the Cell Room. Put in operation in 1967, it received electrolyte that had become heated during electrolysis. The electrolyte was sprayed into a counter-current air stream, cooling as it fell in droplets. It collected in a sump and was pumped back up to the electrolyte distribution launder.

Concurrent with the production capacity increases in Roasting and Concentrate Handling, a process alteration was being developed in the Electrolytic division. The original two cell circuits were being reconfigured, becoming units A and B of an increased capacity

cell circuit. Testing and design work for this altered circuit had been conducted since 1965 by plant engineering, under the supervision of P. M. Jasberg.¹⁶⁵ When it was implemented in 1968, two 15,000 ampere silicon rectifiers supplied D.C. power to the circuit.

The new circuit contained anodes and cathodes that were modified in size and number of components utilized, and which resulted in a 150% increase in zinc production from the 15,000 ampere cell lines. To effect a projected 24 hour zinc deposition cycle for the cells, the resultant cell configuration lowered current density to approximately 85 amperes. The original wooden cell boxes were retained with a slight modification to permit installation of the revised electrolyte feed and discharge system. Flexible Paralene (PVC) liners, manufactured by the Barber-Webb Company, replaced the former lead lining.

The cell bus bar and all components in the cell were redesigned to permit application of mechanized handling equipment for the performance of all production and maintenance operations. Within the new cell, the only components were 21 cathodes spaced between 22 anodes (with integrally attached polyethylene anode guides). Items that had been eliminated were: 28 treated lumber cathode guides, 2 treated and lead covered wooden cell frames (including "insulator support pins, insulators, and cast lead spacer bars"), 14 copper cathode clips and other contact materials (including Everdur studs, Everdur T-bolts, Everdur nuts, and bar material known as "jewelry"), 1 lead outlet pipe casting, 1 plastic cell discharge pipe, 1 plastic feed pipe inlet boot, and 28 silver/lead pins.¹⁶⁶

Anodes for the redesigned cells were "fabricated in a single casting operation," and their strength was improved by a "larger header bar insert," a tapered design "from the bottom of the header bar to the bottom of the anode grid," and larger side ribs "to permit fastening of anode guides to the anode."¹⁶⁷ A polyethylene guide was fastened with PVC bolts to each side of the anode, forming an integral anode/guide assembly. Besides stabilizing the anode, the guide served to maintain the spacing between anode and cathode in the cell box. Openings in the anode guide facilitated circulation of the electrolyte along the space between the cell wall and the guides. Woolf and Crutcher had noted in 1939 that "the distance between anode and cathode [being] but $\frac{1}{8}$ in., it [was] essential that the spacing be uniform, to prevent treeing of the deposit and consequent low current efficiency."¹⁶⁸

Cathodes in the original cells were 4 feet square and $\frac{1}{8}$ in. thick.¹⁶⁹ The cathodes in this redesigned system were 24 in. by 36 in. and .1875 in. thick, and they had a Paralene coating that covered each edge and a $\frac{1}{2}$ in. strip of the face "of the plates (on the sides) and... the top 4 in. of the plate surface (at the solution line area)."¹⁷⁰ This defined the area of deposition, while lengthening cathode life by preventing edge and solution line corrosion.

Electrolyte entered the modified cells from one end and exited through an overflow pipe at the opposite end. This cleared the work area and facilitated the mechanical pulling of cathodes (and anodes, at eight-day intervals).

An overhead bridge crane system supported dual mechanical cathode handling units spaced to service any two adjoining cells. A continuously operating cell transfer and perimeter conveying system transported cathode load carriers to and from the mechanical handling equipment. Two groups of seven cathodes (with 24-hour zinc depositions on them) were pulled and transferred to two empty cathode carriers; the two cathode carriers were released from the bridge and traveled to the stripping area. Two carriers with clean cathodes, from the stripping area, were positioned at the bridge, and the mechanized pulling unit placed them in the vacant cathode area of the cell being serviced. The sequence was repeated three times for each cell to complete the required cathode handling, then the equipment proceeded to the next two cells, in sequence, until the entire cell line was serviced.

At the stripping station, cathode carriers transferred the cathodes to a feeder, which loaded the cathodes individually onto the stripping conveyor. High pressure water jets (10,000 p.s.i.) and stress reversal equipment stripped the zinc deposit from the cathode. A stripping machine unloader removed the stripped cathodes and transferred them to a cathode carrier for transport back to the cell cathode pulling/replacing bridge.

Mechanized equipment for cell maintenance was included in the system redesign. Anodes continued to be cleaned on an eight day cycle. Transport trucks (for anodes and cathodes) were designed to maintain the required "cell spacing" of the anodes and cathodes during cell maintenance activities. This permitted completely mechanized handling for all operations.

An automatic anode cleaning machine was developed which sequentially removed each anode from its transport truck and conveyed the anode up vertically through brushing and high pressure water jet cleaning, followed by flattening rolls. The anode was then lowered to its original location on the anode transport truck. The complete mechanization of these operations eliminated manual handling.

The new 15,000 ampere cell circuits boosted production by 50% in each of the two converted units, raising total Zinc Plant output from 260 to 310 tons per day. With the inception of the Cell Room incentive programs, use of the mechanized pulling bridge, cathode conveying, and cathode stripping system was abandoned. The cathode pulling/replacing operation continued to be mechanized (utilizing monorail hoists), and all cell maintenance equipment continued in operation. The 15,000 ampere cell lines remained in production until the Zinc Plant closure in 1981.

At the conclusion of the sixties, Leaching and Purification underwent a change from the batch method to continuous operation. Five stainless steel tanks replaced the use of wood-stave, lead-

lined leach tanks in 1969. The following year, Purification's existing tanks were converted to continuous operation. The 20 ft. diameter by 13 ft. deep leach tanks were connected in series, solution being pumped between tanks. The tanks were "insulated and contain[ed] steam panels and [were] equipped with axial flow turbine agitators. All of the necessary metering and feeding equipment [was] operated from a central instrument panel."¹⁷¹ If a pump failure occurred, three of the old wooden tanks, relegated to standby, could be used for batch processing while repairs were made to the continuous system.¹⁷²

Two more Burt filters were added to the process during this time, bringing the number of filters in operation to sixteen. These newest filters were larger than the others, having a 6 ft. diameter, versus 5 ft. for the older ones. Other equipment was added to the Burt filter area when sulfide separation was incorporated into the process.¹⁷³

The filter cake that was slurried out of the Burts was fed into a surge tank. From there, it was pumped up to cyclones, which separated out the coarser material. This was pumped into flotation cells for recovery of a sulfide concentrate by use of a frothing reagent. The concentrate was pumped back up to Leaching for retreatment, and the flotation tailing flowed down to the thickener tank to join the fine fraction from cycloning.¹⁷⁴

The Zinc Plant entered its last decade of operation in 1972. It had grown from a 50-ton per day plant in 1928 to an operation capable of producing in excess of 300-tons per day. Its original production was largely from mines controlled by Bunker Hill & Sullivan, but forty years later Robert Bird would write that "about 50% of our concentrates come from mines in which the Bunker Hill Company owns or has considerable interest. The balance is purchased and may come from such areas as Canada and South America."¹⁷⁵ Dependence on ore sources outside of company control had become a significant factor in the Zinc Plant's operations. They had to compete with other plants for these ore receipts. Some of their competitors' plants were more recently built and closer to the ore sources.

Another factor affecting the operation of the Zinc Plant was the growing body of environmental regulations. In an attempt to meet air quality mandates, Bunker Hill undertook the building of a new 610-foot high concrete stack at the Zinc Plant for emission of SO₂ gas in 1976. Completed in 1977, this concrete and steel giant dwarfed the old radial brick stack erected in 1928. Soon after its completion, the original stack was demolished, although the original Cottrell treater remained in place, no longer tied into the plant flow sheet. With the Lead Smelter's new 715-foot tall stack, the Zinc Plant's new stack provided greater dispersion and dilution of exhaust gas.

With the added costs of distant concentrate sources and environmentally related construction, Bunker Hill placed even

greater emphasis on cost saving measures and improvements. One element of this was an incentive plan implemented in the Cell Room in 1971-72. Cell strippers had an eight-load quota of cathodes per eight-hour shift to pull and strip of their zinc. Seventy cathodes made up one load. Experienced hands were able to achieve their quota over a relatively short time, often stripping a load within a 15-25 minute period. Under the incentive plan, a worker who stripped loads in excess of the quota received an hour's pay for each load stripped, and he was allowed to leave work a half-hour early. This not only saved money in terms of time, but reduced labor turnover in the Cell Room, as it became more economically attractive in spite of the rigors of stripping.¹⁷⁶

In the early-eighties, Bunker Hill used 45 cells in the north end of the Electrolytic division for the test installation of a new electrolyte feed system. This utilized two main feed lines with 45 separate feeder lines branching off to the cells. 23 of these feeder lines entered cells from the northern side, and 22 entered from the south. The head gained by use of the main pipelines supplied a constant flow to the feeder pipes, which arced up and into the cells. The pipes were a DuPont polymer product known as Sclairpipe, and they were notable both for their ease of cleaning and resistance to deposit buildup. Application of a vibrator served to loosen up any accumulated deposits. Under the old system, feed launders were subject to clogging, thus they were cleaned every time a cell was repaired.¹⁷⁷

Despite these attempts by the Company to remain competitive, the Zinc Plant was approaching the end of its operating life. Bunker Hill had become a wholly owned subsidiary of Gulf Resources in a 1968 takeover, and the Texas-based corporation was faced with deciding the long-term future of their Idaho subsidiary in 1981. The result of that was a closure announced by Gulf in late-August of that year. By 1982, most of the Zinc Plant's operating staff had been laid off, and much of the operational equipment was being scrapped or sold. An effort was made to revive the facility soon after closure, when the Bunker Limited Partnership was formed, and that company purchased the Bunker Hill holdings, but the plant remained closed, and Bunker Limited's involvement became subject to bankruptcy proceedings in 1990.

In 1993, the Zinc Plant stood empty, twelve years of dereliction having rendered parts of the plant physically unsafe. As part of the 21-square mile Bunker Hill Superfund Site, the Zinc Plant is slated for demolition, with subsequent remediation of the former plant area.

H. Summary: The Sullivan Electrolytic Zinc Plant, Its People and its Place in American Industrial History

The plant that was built in the years 1926-28 brought significant change to the community known as Silver King. Several homes and a school had been built on the floor of Government Gulch,

adjacent to the Silver King Mine and Mill, located on the eastern ridge slope.¹⁷⁸ The Union Pacific Railroad's Sierra Nevada Mine branch line swung through the community and climbed up that ridge, heading for its namesake mine. When Zinc Plant construction began in 1926, it became apparent that the scale of the work would have a substantial impact on existing houses and structures within the area. Mallette issued a memorandum on May 23, 1927 advising Sullivan personnel of new construction cost accounts, including one for "Removal of Structures. In this will be included the cost of tearing down and disposing of the materials from all old buildings or other structures which may be removed from the site."¹⁷⁹ One of the largest of these structures to be removed was the Silver King Mill, which was situated near the area where the Boiler House was to be erected as part of the Upper Plant. Other structures in the immediate area of the plant were undoubtedly removed, but residences to the south of the plantsite were to remain, providing homes close to the operating Zinc plant for workers like Ernie Lauer, a member of the Roasting department crew and Nan McClung, the Main Office janitress (and a member of the original Zinc Plant Twenty-Year Club).¹⁸⁰

There was also the issue of residences for Zinc Plant supervisory staff. In the completed plant design, six of these were to be placed along a curve at the southwestern edge of the complex, facing the Main Office. Mallette addressed the issue of present occupancy when he wrote to Easton in July, 1927, advising him that "arrangements are practically completed for clearing site for houses. There are a number of old shacks on this location which will have to be removed and negotiations with the owners are about concluded."¹⁸¹ Three months later the last of the houses had been removed, and "bids [were] now being taken on the [staff] houses and work will start shortly."¹⁸² The Zinc Plant residences that Woolf and other supervisors were to occupy were going to be substantial homes in a well landscaped setting.

Early in 1929, Ernest R. Crutcher and Henry P. Ehrlinger, two of the young metallurgists who assisted U.C. Tainton and Wallace Woolf in adapting the Tainton-Pring method to Star Mine ore concentrates, were summoned to a meeting. They were told that a coin-flip on the following day would decide who stayed on as Woolf's assistant superintendent, and who would go with Tainton to East St. Louis, Illinois to participate in planning for a second plant using his process. The outcome of that toss established Crutcher at the Zinc Plant, and Ehrlinger went on to a distinguished consulting and teaching career.¹⁸³ The plant that Ehrlinger helped to design for the Evans-Walloway Company functioned only a brief time, succumbing to the economic climate of the Great Depression. When it re-opened in 1940, it was remodeled as a low density operation by the American Zinc Company.¹⁸⁴ The Sullivan Electrolytic Zinc Plant became one of a kind, the only zinc plant in the world to successfully operate on a high current density, strong acid basis for more than fifty years.

Urlyn C. Tainton moved from East St. Louis to Baltimore, Maryland, where he established his Tainton Research Corporation in 1931. He directed research efforts towards production of an electrolytically galvanized wire that became known as Bethanized wire. Its use by English companies in "balloon barrage cables and submarine nets during World War II" was part of Tainton Research Corporation's collaboration in the war effort.¹⁸⁵ Tainton died shortly after the conclusion of the war, on August 29, 1945 in Baltimore.

Woolf and Crutcher worked together, until 1945, when Crutcher succumbed to ulcer-related conditions while seeking treatment at the Mayo Clinic in Rochester, Minnesota. Angus Bethune was promoted to take his place as assistant superintendent. Bethune had been hired out of the University of California as a metallurgist in 1928, and one of his early tasks was development of the magnetic separation of the roast. After this process was abandoned, he supervised the startup of the Cadmium Plant in 1930, continuing on with Sullivan and Bunker Hill, in various capacities, until he was promoted to Manager of Metallurgy for the Company in March of 1957.¹⁸⁶ Bethune left Bunker Hill for other employment in the field of zinc metallurgy in 1964, after a thirty-four year career, much of it being spent at the Zinc Plant.¹⁸⁷

Wallace Woolf retired in 1960 to Salt Lake City, Utah, his hometown. He was highly regarded by both his employees and the industry that gave him his great opportunity, earning the nickname "Mr. Zinc." Woolf retained an interest in the Zinc Plant's activities, returning for the plant's 50th anniversary celebration in November of 1978. He lived to be one hundred, passing away in Salt Lake City, in 1990.¹⁸⁸ As Zinc Plant superintendent, Woolf and his family had been among the original occupants of the residences established at the Zinc Plant in 1928. That semicircle of six homes housed several members of the plant's staff until the structures were demolished in the early seventies. Woolf was succeeded as superintendent by Angus Bethune, who was in turn succeeded by Walter Schmittroth, Douglas Baker, Robert Bird, Carlos Smith, and John Siddle (the superintendent at the time of closure).

As noted earlier, North Mill pilot plant employees like Emmett Waltman, Gregory Popoff, and A.B. Henwood continued their service at the inception of Zinc Plant operations in November, 1928. Emmett Waltman, who began as the Carpenter Crew foreman, became the superintendent of Maintenance and Construction for many years, and a valuable assistant to Wallace Woolf. As Construction Superintendent, Waltman supervised the various Zinc Plant expansions until his retirement in July of 1960. His last project was the Bunker Hill Phosphoric Acid Plant, built to the north of the Zinc Plant and completed in July, 1960.

Popoff, who had fled Russia during the 1917 Bolshevik Revolution, continued his metallurgical research in the Zinc Plant, becoming the director of Research and Metallurgy for the Sullivan Mining Company later in his career.

Curly Henwood became the first superintendent of Leaching. He was an avid reader on the subject of metallurgy and amassed a considerable holding of written materials on that and related subjects. When he donated his collection to the Central Research and Analytical Laboratory built in 1967, the books became part of the Henwood Library within that facility.¹⁸⁹

Joining Henwood on the original Zinc Plant supervisory staff were Charles Noonan in Roasting, Walter Leamy in Purification, and Robert Lafferty in the Electrolytic and Melting departments. Glenn Waltman had been part of the crew that labored on the plant's construction, and he remained as the Yard Crew supervisor at the Zinc Plant, later becoming a construction supervisor for various Bunker Hill projects. Louis Warner was the original superintendent of the Mechanical Maintenance Crew, Steve Sivara headed the separate maintenance area of Lead Burning, and Arthur V. Dunkle supervised the Zinc Plant Electrical Crew, with the assistance of Lenoir Fisher (who later filled the Electrical Crew superintendent's position for many years). Henry Biotti was the original head of Warehouse and Purchasing, and Vernon Roehl served as the first office manager at the Sullivan Zinc Plant. Plant engineer O.J. Jasberg had been involved with Zinc Plant design work before the start of production. He had worked on the design of the Burt filters being manufactured by the Joshua Hendy Ironworks in San Francisco, engineering the needed design changes that would ensure maintenance of a vacuum and the operation of the filters under pressure.

Other men who began their employment with Sullivan dedicated their working lives to the production of high purity zinc and cadmium. Connie Neubauer succeeded Louis Warner in Mechanical Maintenance, and he was followed by Ed Sullivan, who had begun his service by helping to make the first anodes used in the Cell Room. Upon the beginning of plant operations, Sullivan worked as a pipefitter.¹⁹⁰ Ward Williams began his career on the Carpenter Crew, eventually succeeding Emmett Waltman as supervisor. In the Research and Analytical Laboratories, Walter Schmittroth and Leo Baumeister began their long careers with Sullivan. Both men were highly regarded for their knowledge of metallurgical chemistry.¹⁹¹ Schmittroth became Zinc Plant superintendent, and later was the head of the Central Research and Analytical Laboratory.

In that early period of Zinc Plant operations, other men came to work and established themselves on the numerous crews that were vital to the plant's processes. Robert Behrens and Guy Martello both began working early in the Zinc Plant's history. During their careers, they were promoted to supervisory positions in the Cadmium Plant. Patrick Damiano learned the craft of lead burning under Sivara and followed him as supervisor. Rudy Schilling worked on the Boiler Crew in maintaining an important component of plant equipment. He was followed by Al Hise as foreman of the Boiler and Pipefitter Crew. Samuel Keller worked under Schmittroth in the thirties, later becoming an assistant plant superintendent. Dante

Bisaro brought bricklaying skills to the Zinc Plant. He came to work in 1931, succeeding John Vergobbi as the plant bricklayer. He was responsible for the laying of the fire brick, made by A. P. Green, that was used in the Wedge roasters. It has been estimated that 80,000 bricks of varying shapes were required to completely reline a roaster.¹⁹² He also worked with the dense clay Duro bricks made by Harbison and Walker. These were used on the Stripping Room floor and in other plant locations that required protection from corrosion. Beginning in 1938, the Duro bricks were also laid against the lead lining of the leach tanks.¹⁹³ Bisaro worked until the end of his life at the Zinc Plant, passing on his skills to his sons Arthur and Derino.¹⁹⁴

The Sullivan Electrolytic Zinc Plant represented a significant addition to employment opportunities in the Coeur d'Alenes. Many young men began their worklife here. Women, who had previously been limited to office work, became an important element of the workforce during World War II and in the closing decade of Zinc Plant operations. People, who began by stripping zinc from cathodes, worked their way up the corporate ladder. Some, like Ted Turnbow and Jack Clemson, used their maintenance experience to become superintendents in Mechanical Maintenance. Others went on to Company careers outside of the Zinc Plant proper. Charles Kiliman was promoted to head of Purchasing for Bunker Hill, Robert Graves became the Traffic superintendent, Gerald Turnbow served as vice-president of Public Relations, and James Halley was one of the last presidents of the Bunker Hill Company.¹⁹⁵

Even though the Zinc Plant attracted a dedicated corps of long term employees, high labor turnover was a feature of plant life, just as it was at the Bunker Hill Lead Smelter and in Coeur d'Alene District mines. The work was arduous, and the conditions weren't desirable to some. A pattern developed in the district that was used to advantage by the Zinc Plant. Men who preferred to work outdoors found employment as loggers. When winter set in, and the woods work closed down, these same men came to work at the Zinc Plant. In the spring and summer, their places were taken by college students, home for the break between semesters. This routine became known as the "itinerant schedule."¹⁹⁶ These workers filled a valuable niche in work scheduling for the Zinc Plant.

In 1949, the Zinc Plant was the first of the operations affiliated with Bunker Hill to form a Twenty-Year Club, honoring those employees with lengthy service. Through the devoted efforts of employees like Bud Morris and Wayne Bushnell, the club has continued to hold their yearly meetings, now open to anyone who worked at the Zinc Plant. These annual gatherings attest to the enduring loyalty and friendship that is a hallmark of the industrial work experience in America. The collective memory of this human resource is an extremely important part of the Zinc Plant's historic value. Photograph ID-28-7 shows members and guests gathered at that inaugural dinner of March 15, 1949.¹⁹⁷

The beginning of production from the Sullivan Electrolytic Zinc Plant in 1928 was a propitious event for the die-casting industry in this country. Commercial quantities of high purity zinc metal became available for the ever-growing number of applications that die-casting was being used for. Bunker Hill Special High Grade zinc was the purest commercial zinc (99.99+%) available, and as Bird has noted it "became the life blood of the die cast industry."¹⁹⁸ Being remarkably free of impurities, the Zinc Plant's product was ideal for alloying with other metals to produce high quality castings. Die-casting had been in use by industry many years prior to the existence of the Sullivan Zinc Plant, but the spelter that was produced by the retort method still contained sufficient percentages of other elements to pose quality control problems when the zinc was used with other metals in alloy products. Ehrlinger referred to this in his engineering thesis when he wrote of a problem encountered by the U.S. Army Ordnance Department in World War I: "It was found that in the rolling of brass for shells the impurities made the brass brittle and cracks were formed which caused shell failures and subsequent gun failures."¹⁹⁹

The automotive industry benefitted from the availability of good die cast products. From a single, precisely machined mold, thousands of usable products like door handles and carburetors were cast. The cost of machining an individual item from any metal or alloy would greatly exceed that of a mass produced casting.²⁰⁰ All that was required was a die, or mold, that could be opened and closed, molten metal, and equipment to fill the die. Typically, a piston or a pressure valve, in conjunction with air pressure was used to fill the injection chamber with molten metal, and, after the metal had cooled, the die could be opened and the complete casting removed. By this method, single and multiple castings were produced.

Other zinc plants in North America and Europe sought to achieve the standard set by the Sullivan Electrolytic Zinc plant. Theirs and the Sullivan's output established captive markets for high purity zinc. In the post-World War II era competition from another source challenged zinc's dominance. The increasing use of plastics and other synthetic materials offered a lower-cost alternative to zinc alloy die-casting that significantly reduced the demand for zinc. The resulting decline in the price of zinc was another factor in Gulf's decision to close the Zinc Plant.

The Sullivan Electrolytic Zinc Plant was unique for its adaptation of the Tainton-Pring process of high current density, strong acid sulphate solution electrolysis to Coeur d'Alene District ores and the use of that method throughout the plant's fifty-three years of operation. Process additions increased and diversified plant output (in terms of byproduct sulfuric acid and alloy products). In its later years, the Zinc Plant saw process modifications in the form of Cell Room mechanization and continuous

Leaching and Purification in an attempt to make the operation more competitive. The environmental costs, distance from and competition for ore receipts, and the depressed price of zinc in the seventies all helped to negate the creative efforts of the Zinc Plant's staff. The 1981 closure of the Bunker Hill Zinc Plant mirrored similar plant closings of this era.

The attention to detail that characterized the work performed at the North Mill pilot plant carried over into Zinc Plant operations. Schmittroth's work in developing the Pretreatment process stands as a good example of this. Many other examples exist, too, from machinist Frank Vanderpool's development of a machine for manufacturing the copper clips that were used in the Electrolytic division's cells to Ken "Arky" Allen's skill in producing commemorative castings in the Melting division.²⁰¹ The Sullivan Plant's most remarkable achievement, however, was the enduring effort to sustain and improve production of high purity zinc metal. In Photograph ID-28-8, a stack of Special High Grade Bunker Hill brand zinc is prominently displayed, flanked by U. C. Tainton and E. R. Crutcher.

I. Zinc Plant Building Structural Information (Refer to Figure 1).

Upper Plant

- 1.) Cottrell treater: Built 1928 (steel and wood frame, wood, brick, and metal clad); 8,784 sq. ft.

Dust in the roaster gas stream was electrostatically precipitated onto plates and recovered for re-roasting. Note: 250 foot brick stack was demolished circa 1978, and only a brick wall chamber leading to the stack remained.

- 2.) Stack: Built 1976-77 (steel reinforced concrete, with 6 ft. diameter FRP [fiberglass reinforced polyester] chimney; 610 feet high.

- 3.) Balloon Flue: Built 1928 (steel frame, metal clad); 10 feet wide by (approximately) 1000 ft.

Roaster gases exhausted through this to the Cottrell. Dust in the gas stream that settled in the flue was recovered for re-roasting.

- 4.) Flue: Built 1977 (FRP duct with steel supports); connected tall Stack to Fan House.
- 5.) Fan House: Built 1977; fan propelled SO₂ gas to Stack.
- 6.) Acid Plant: #2 Chemico Acid Plant- Built 1965

7.) Acid Plant: #1 Monsanto Acid Plant- Built 1953.

The Acid Plants included various reaction and temperature control vessels, tanks, pumps, and cooling systems. They each had steel frame and concrete block Control Houses (#1 is 1275 sq. ft. and #2 is 600 sq. ft.). Byproduct sulfuric acid was produced by these plants.

8.) Concentrate Storage/Thaw Shed: Primary ore storage bins built 1927 (reinforced concrete, wood and steel frame, wood clad); addition 1937 (reinforced concrete, wood and steel frame; 4,536 sq. ft.; Thaw Shed enclosure- Built 1946 (wood frame); addition 1954; 5,603 sq. ft.; Concentrate Bins built 1952 (reinforced concrete and wood clad, wood and steel frame); 7,169 sq. ft.9.) Roaster Floor (customarily referred to as Roaster Department): Built 1927 (steel, concrete, and wood frame, metal and wood clad); additions 1947, 1948, 1951 (same structural materials as original); approx. 41,472 sq. ft.

This department contained the original Wedge roasters, current flash roasters, and related process equipment.

10.) Cottrell: Built 1953 (steel and wood frame, metal and wood clad); addition 1956 (same structural materials); approximately 13,116 sq. ft.11.) Manganese Ball Mill: Built 1953 (steel frame, wood clad); 741 sq. ft.12.) Leach Floor: Built 1927 (steel frame, wood clad); additions 1953, 1956 (same structural materials); 16,128 sq. ft.

This floor contained the lead and brick lined, wood stave batch leach tanks, stainless steel continuous leach tanks, leach slurry storage tanks, Burt solution storage tanks, copper sulphate storage tank, and related process equipment.

13.) #1 Area Shack: Built 1967 (wood frame, metal clad); 480 sq. ft.14.) Surge Tank section: Built 1937 (steel frame, wood clad); addition 1950 (same materials); 2,550 sq. ft.15.) Filter Floor (Leach Department south end/Purification Department north end): Built 1927 (reinforced concrete and steel frame, wood clad); additions 1937, 1948, 1950,

1956 (same materials); 29,270 sq. ft.

This floor contained the purification tanks and Shriver filter presses for the Purification Department; the Burt filters and a flotation cell were part of the Leach Department.

- 16.) Tank Floor: Built 1927 (reinforced concrete and steel & wood frame, wood and reinforced concrete clad); additions 1948, 1957 (same materials); 15,120 sq. ft.

This floor contained Purification Department neutral solution storage tanks on the north end and Leach Department return electrolyte storage tanks on the southern end.

- 17.) Residue Floor (Leach Department): Built 1927 (steel and wood frame, wood clad); addition 1950 (same materials); 12,150 sq. ft.

This floor contained drum filters, dryers, wash water tanks, and related process equipment. The wash water was used in the Burt filters, while the drum filters and dryers prepared Leach residues for rail shipment to the Lead Smelter.

- 18.) Oil House: Built 1928 (reinforced concrete); 700 sq. ft.

- 19.) Thickener Tanks (Residue Department): Built 1927 (contained wood stave thickener tanks); additions 1950, 1954 (open, wood frame canopy).
Leach residues thickened here, prior to filtering.

- 20.) Welding Shop: Built 1954 (steel frame, pre-engineered metal clad); 5086 sq. ft. Removed 1985.

Note: This structure replaced the original 1927 Machine Shop.

- 21.) Machine Shop: Built 1927 (wood frame); 4,252 sq. ft.

Note: This was the original Warehouse; the Machine Shop was moved into this building in 1951.

- 22.) Warehouse: Built 1950 (reinforced concrete); 23,832 sq. ft.

- 22.) Hydrogen & Oxygen Storage/Acetylene Generation: Built 1964 (CMU [concrete masonry units]); part of Warehouse square footage figure.

22.) Pipe Shop: Built 1965 (CMU); part of Warehouse figure.

23.) Compressor House: Built 1937 (steel frame, wood clad); addition 1952 (same materials); 2670 sq. ft.

Note: Compressors were part of the original plant equipment in 1927, but they were housed in Zinc Plant operating areas such as the Leach Floor and Cell Room.

24.) Boiler House: Built 1928 (wood and steel frame, reinforced concrete, metal clad); 2,768 sq. ft.

25.) #5 Roaster (map area labeled "Roaster Bldg."): Built 1967 (steel frame, metal clad); approx. 63,000 sq. ft.

This facility contained the large flash roaster and related process equipment. Calcine and dry concentrate silos stood to the southeast of the building.

26.) Steel Flue: Built 1967; this conveyed #5 Roaster gas to the #2 Chemico acid plant, and the support structure also contained a calcine conveyor system leading to the Leach Department.

27.) Concentrate Handling: Built 1967 (reinforced concrete and steel frame, reinforced concrete and metal clad); 28,080 sq. ft.

This building contained equipment for storage and processing of incoming concentrates. This included charge preparation conveyors, a pretreatment slurry tank, filter, dryer, and flotation cell.

28.) Carpenter Shop: Built 1937 (wood frame); addition 1963; 4,112 sq. ft.

Note: The eastern end of this building contained the original Lead Shop.

29.) Lead Shop: Built 1955 (wood frame); 2,448 sq. ft.

Note: This facility was built when the Carpenter Shop expanded into the former Lead Shop area.

30.) Lumber Shed: Built 1937 (open, wood frame); 790 sq. ft.

31.) Framing Shed: Built 1937 (wood frame); 3200 sq. ft.

Note: This structure was later used as a Bulk Storage Warehouse and as a Phenolic Treatment Facility for dimensional lumber.

- 36.) Mist Precipitators: Built 1954 (part of SO₂ gas purification for Acid Plant); no square footage listed.
- 37.) Rectifier Building: Built 1953 (provided direct current for operation of dry Cottrell and Mist Precipitators); no materials or square footage listed.
- 38.) Paint Shop: Built 1975 (steel frame, pre-engineered metal clad); 800 sq. ft.
- 39.) Pretreatment Plant: Built 1953 (steel and reinforced concrete frame, wood clad and CMU); 9,583 sq. ft.

This plant contained a concentrate dryer and process equipment for the removal of magnesium from Pend Oreille Mining District ores. Equipment included agitator tanks, acid feed system, siphons, filter, and flotation cells.

- 40.) Cadmium Plant: Built 1929 (reinforced concrete, wood clad); additions 1948, 1963 (wood frame, wood clad); 13,348 sq. ft.

This plant contained process equipment for the production of pure, metallic cadmium from Purification residues.

- 41.) Track Scales: No date, materials, or square footage listed (used for weighing of all incoming and outgoing rail shipments).
- 70.) Zinc Dust Tower: Built 1956 (pneumatically conveyed zinc dust was received here prior to use in Purification); no materials or square footage listed.

Note: this structure replaced an earlier tower that was removed during northward expansion of the Filter Floor in 1956; in 1967, a secondary conveying system accessed the Zinc Dust Tower to directly supply purification tanks with zinc dust.

Lower Plant

- 42.) Casting Room (Melting & Casting Department, Stripping Room): Built 1927 (steel and wood frame, gunnite clad); addition 1956 (steel and wood frame, wood and metal clad); 18,774 sq. ft.

Zinc was stripped from the cathodes in the Stripping Room at the southern end of the facility, then the bundles of stripped zinc were melted in furnaces, prior to being cast

in shapes. Note: The Stripping Room also served as the original anode casting facility; it was always used for "pickling," or pre-treating, the new cathodes, and for copper plating contact areas of cathode header bars.

- 43.) Zinc Storage (Melting & Casting Department): Built 1937 (steel and wood frame, wood clad); 8,346 sq. ft.

A 7 ft. by 123 ft. loading platform was part of the facility.

- 44.) Generator Room: Built 1927 (steel frame and reinforced concrete, gunnite clad); Additions 1937, 1956 (steel frame, wood clad); 20,934 sq. ft.

This room contained the motor generator sets and arc rectifiers used in supplying direct current to the electrolytic cell circuits.

- 45.) Cell Room (Electrolytic Department): Built 1927 (steel and wood frame, gunnite clad); additions 1937, 1948, 1956 (steel and wood frame, wood clad); 100,204 sq. ft.

The electrolytic deposition of pure, metallic zinc on aluminum cathodes occurred within the cells housed in this structure.

- 46-50.) Manganese Room: Built 1927 (#46, steel and wood frame, gunnite clad); additions 1937 (#47, same materials), 1948 (#49, wood frame), 1956 (#48, steel and wood frame, wood clad), 1961 (#49, steel frame, wood clad); 42,531 sq. ft.

Thickener tanks received return electrolyte, containing precipitated manganese dioxide, that was discharged from the Cell Room sump; balance tanks received return electrolyte and additions of neutral solution; and pumpover tanks held spent electrolyte until it could be pumped to a return electrolyte storage tank on the Tank Floor.

- 50.) Electrical Distribution & Control Room: Built 1956 (reinforced concrete and steel frame, concrete block); addition 1964; 1,424 sq. ft.

- 51.) Manganese Dioxide Thickener Tank: Installed early-seventies (Paraline lined tank with FRP covered concrete containment).

- 52.) Manganese Recovery Room: Built 1963 (steel frame, metal clad); 502 sq. ft.

- 53.) Anode Building: Built 1956 (steel and wood frame, metal and wood clad); addition 1963 (rigid frame, metal clad); 8,730 sq. ft.

Anodes were cleaned in this facility, which also contained anode fabrication equipment (housed in the 1963 addition). It replaced an earlier Anode Shed and cleaning platform, located in the area of the 1956 Cell and Generator Room expansions. Note: The Anode Building received a northern extension in the late-sixties.

- 54.) #4 Area Shop: Built 1973, removed 1985 (Wood frame, metal clad); 1080 sq. ft.

- 55.) Reservoir & Pump House: Built 1927-28 (Concrete, Wood and steel frame); 22,500 sq. ft. (reservoir), 621 sq. ft. (pump house).

Note: An undated addition was made to the Pump House.

- 56.) Air Conditioner Wings: Built 1937 (steel and wood frame, wood clad); addition 1948 (wood frame); 1137 sq. ft.

Air conditioners housed in these wings provided a constant air temperature within the Generator Room.

- 57.) Electric Shop: Built 1929 (wood frame, reinforced concrete and wood clad); 2,368 sq. ft.

- 58.) Maintenance Office and Garage: Built 1937 (wood frame); addition 1946 (same materials); 1,488 sq. ft.

- 59.) Dry House: Built 1928 (wood frame); additions 1937, 1948, 1956, 1957 (same materials); 7,377 sq. ft.

- 60.) Garage: Built 1927 (wood frame); building and roofed shed additions (wood frame), date not listed; 3,584 sq. ft.

- 61.) Main Office: Built 1928 (reinforced concrete foundation, wood frame, brick veneer); 7,575 sq. ft.

- 62-63.) Cooling Tower/Pump House: Built 1966-67 (steel frame and reinforced concrete, metal clad); 1372 sq. ft.

Following cooling, electrolyte was pumped to the cell distribution circuits from here.

- 65.) Zinc Dust Building: Built 1956 (reinforced concrete, steel and wood frame, metal clad; open wood frame with chicken wire and building felt cover); 7,353 sq. ft. Zinc

dust for use in Purification was produced here and pneumatically conveyed to the Purification Department.

Note: Zinc dust manufacture was originally done in the area of the 1956 expansion of Melting & Casting.

65.) Trolley & Lift Truck Service Shed: Built 1956 (reinforced concrete, steel and wood frame, metal clad); addition 1960 (same materials); part of square footage listed for Zinc Dust Building.

65.) Drossing Plant and Dross Storage: Built 1962 (steel frame and pre-engineered metal clad); 3,008 sq. ft. Dross from Melting & Casting was treated here for recovery of metallics, and the dross was stored in the adjacent shed.

Note: Drossing originally took place within the 1927 Melting & Casting Department.

66.) Laundry Bridge: Built 1927 (steel truss covered bridge); no square footage listed. The Laundry Bridge gravity-delivered neutral solution from Tank Floor storage via a launder to the balance tanks in the Manganese Room; it also carried steam, water, and return electrolyte lines, along with electrical circuits.

Auxiliary Structures

32.) Zinc Warehouses: Erected 1954, removed 1982, 1992 (Quonsets with passageway); 4,920 sq. ft.

33.) Machine Storage: Erected 1954 (Quonset); 3,024 sq. ft.

34.) Sand Storage: Erected 1954 (Quonset); 5,600 sq. ft.

35.) Warehouse: Erected 1961, removed 1985 (rigid frame structure); 5,760 sq. ft.

64.) Pump House: Built 1956 (steel and wood frame, wood clad); 1,800 sq. ft.

This structure was initially a cooled electrolyte pump house. It was last used for neutralizing acidic waste water; an adjacent structure contained a filter for removing precipitated mercury, prior to discharge of the water into the #004 Pipe Line, which led to the CIA (Central Impoundment Area).

67.) Sulfuric Acid Tank Farm: Nine acid tanks not shown.

Note: The first four were installed in 1953, when the #1 Acid Plant was built; the five additional tanks to the north were installed at later dates.

- 68.) Acid Purification Building: Built 1972 (steel frame and CMU, metal clad); 2,192 sq. ft.

Food-grade sulfuric acid was obtained through a purification process developed by the Bunker Hill Company and housed in this building.

- 69.) Rail Loading Dock: Built 1954 (steel frame and reinforced concrete); 7,060 sq. ft. Note: The dock was adjacent to the northern and western edges of the Quonset storage facilities.

- 75.) Gate House: Built 1957 (wood frame); 364 sq. ft.

Note: This Gate House replaced the one removed in the course of building the Anode Cleaning facility.

- 76.) Stairways: Along southern side of Upper Plant Main Building.

Sources Consulted (section I):

Blickle, Charles P. Appraisal Report- The Bunker Hill Company.
Milwaukee: American Appraisal Company, 1977.

Jasberg, Peter M. Interview by author, 5 August 1993, Kellogg, Idaho.

Sullivan, Ed. Telephone interview by author, 5 August 1993, Cataldo, Idaho.

"Zinc Plant Building & Foundation Information Map." Bunker Hill Company (Drawing no. 1056-A-L) 18 September 1968. Pintlar Documents Storage Record.

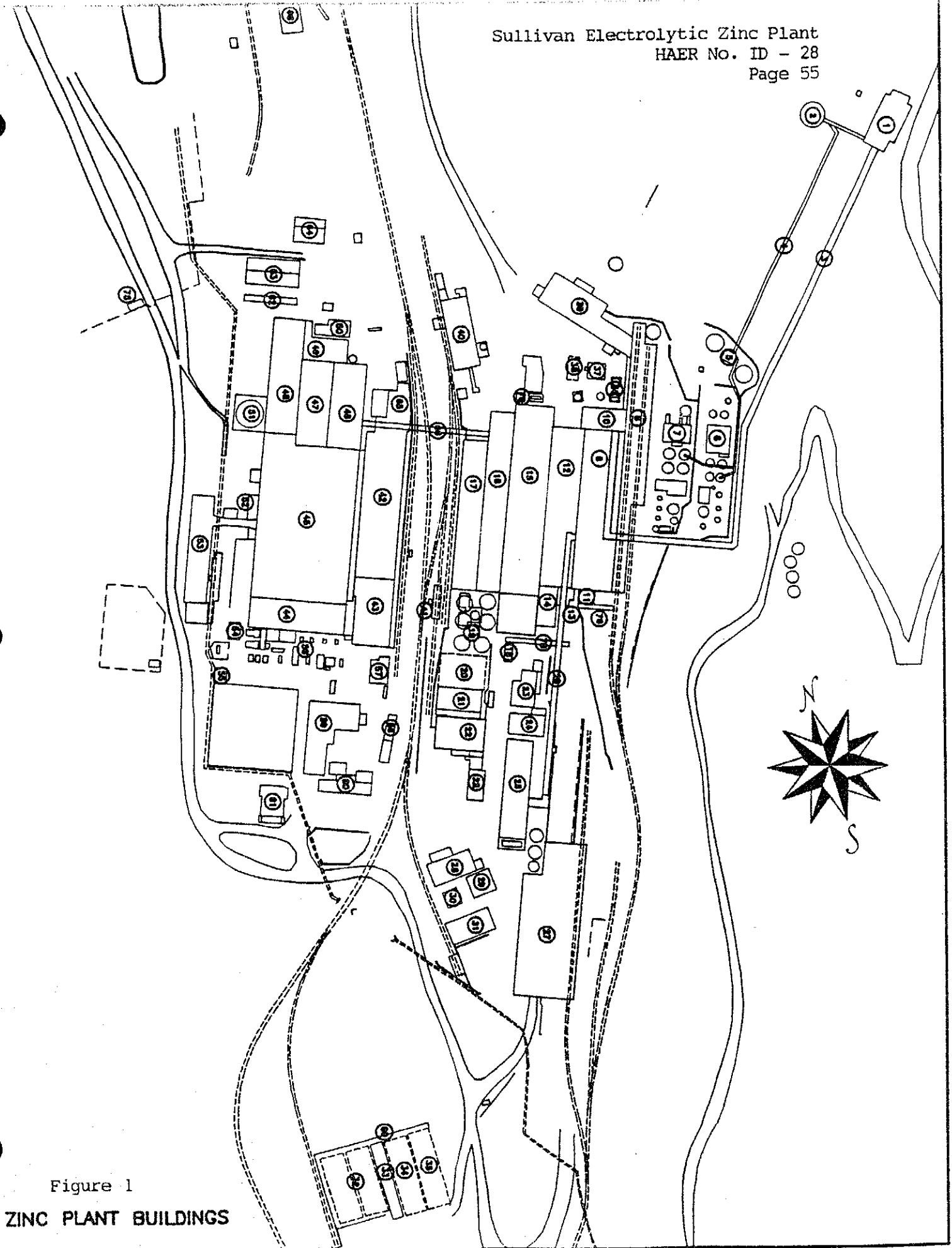


Figure 1
ZINC PLANT BUILDINGS

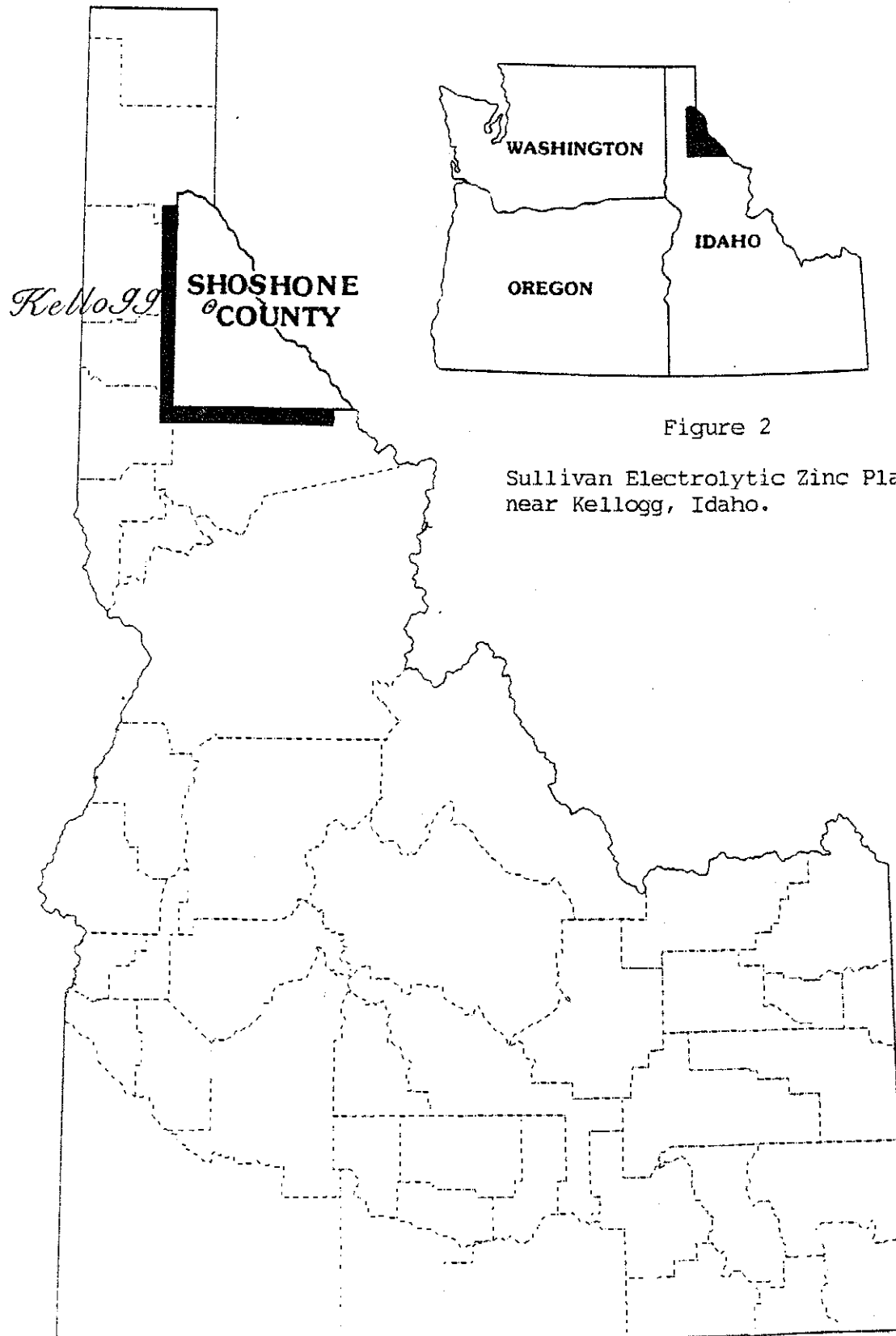


Figure 2

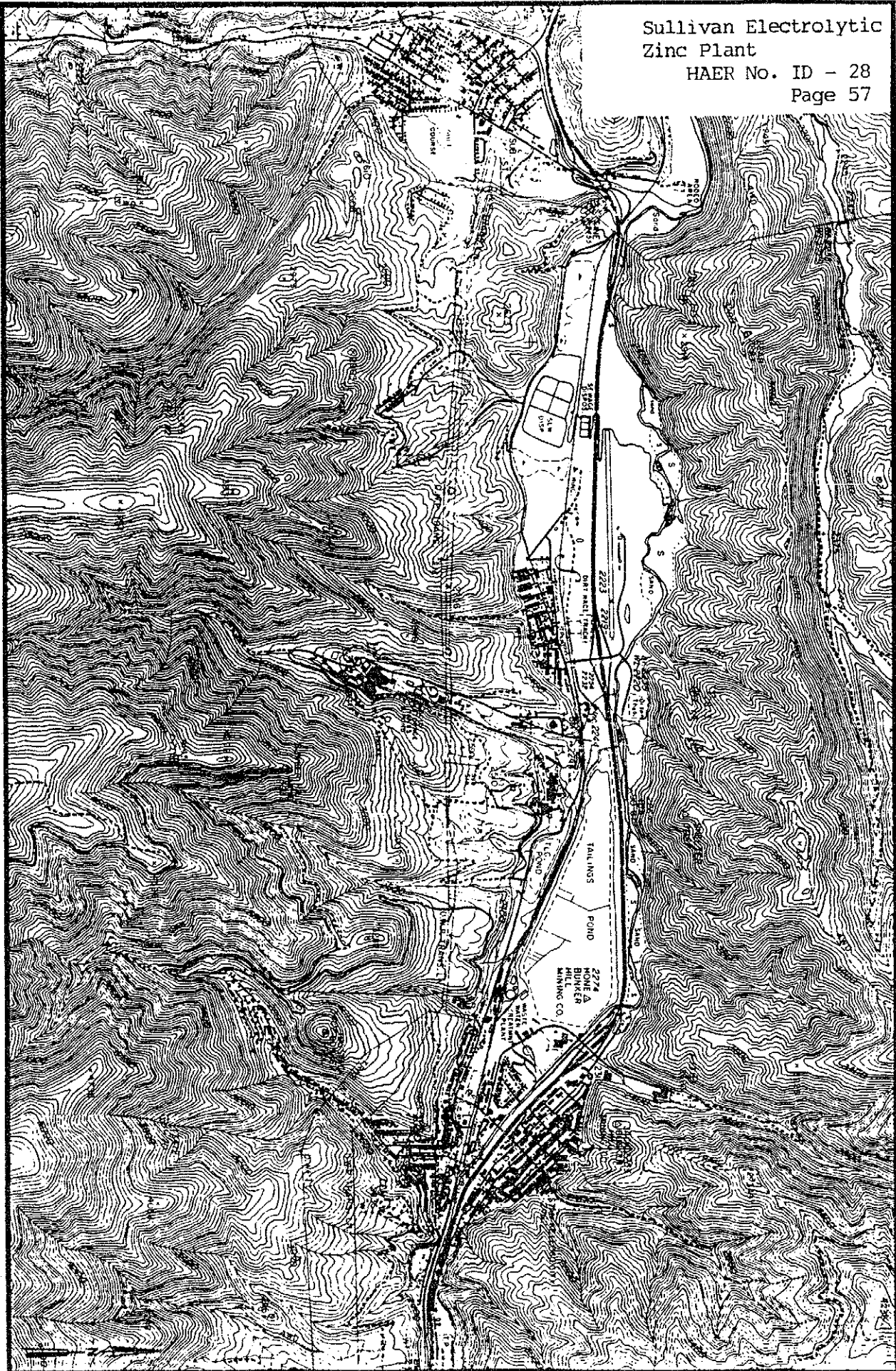
Sullivan Electrolytic Zinc Plant
near Kellogg, Idaho.

Sullivan Electrolytic
Zinc Plant

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- Figure 3
Kellogg Area
- 1 = Bunker Hill Lead Smelter
 - 2 = North Idaho Phosphate Co.
 - 3 = Sullivan Electrolytic Zinc Plant
- K = Kellogg
S = Smelterville

Scale in miles
0 1 2 3



NOTES

1. Carle R. Hayward, An Outline Of Metallurgical Practice, (New York: D. Van Nostrand Company, Inc., 1952), 221.
2. H.B. Pulsifer, "The Production of Electrolytic Zinc," Anaconda Copper Mining Company, April, 1920. This is an unpublished paper contained in the unpublished "Zinc Report, 1923," ("Butte District" section, 10), by A.V. Udell, prepared for Frederick W. Bradley of the Bunker Hill Company, Pintlar Documents Storage Record (hereinafter P.D.S.R.).
3. Angus Y. Bethune, Metallurgist, interview by author, 24 March 1993, Spokane, Washington.
4. Hayward, Metallurgical Practice, 245.
5. A. V. Udell, "Zinc Processes Compared," 8, in "Zinc Report, 1923" P.D.S.R.
6. Bethune, 24 March 1993.
7. Udell, "Zinc Processes Compared," 46-47, in "Zinc Report, 1923".
8. Hayward, Metallurgical Practice, fig.185, 269.
9. Udell, "Zinc Processes Compared," 45, in "Zinc Report, 1923".
10. Katherine G. Aiken, "Bunker Hill versus the Lead Trust, The Struggle for Control of the Metals Market in the Coeur d'Alene Mining District 1885-1918," Pacific Northwest Quarterly 84, no. 2 (1993), 46.
11. W.G. Woolf and E.R. Crutcher, "Making Electrolytic Zinc at the Sullivan Plant," in "The Bunker Hill & Sullivan Enterprise Today," Engineering & Mining Journal 140, no. 8, (1939), 72.
12. W.C. Smith, "Report on The Tainton-Pring Electrolytic Zinc Process As Operated at Electrolytic Zinc Works, Martinez, California," an unpublished report prepared for U.S. Metals Refining Co. of Chrome, N.J., in Udell's "Zinc Report, 1923" (Tainton-Pring Process section, 56). In spite of the listed capacity, Mr. Smith stated that "4710 [lbs.] per 24 hours has been the best record made."
13. H.P. Ehrlinger, "Bunker Hill Zinc Plant," unpublished consultation of 14 August 1971, 2, P.D.S.R.

14.Udell, "Memorandum on Tainton-Pring Patents For Electrodeposition of Zinc," in "Zinc Report" ("Zinc Processes Compared" section, 16).

15.Ibid., 17.

16.Ibid. This comment was extracted from the American Electro-Chemical Society, Vol. xxv (1914), 295.

17.Ed Whitley, Metallurgist, interview by author, 21 April 1993, Kellogg, Idaho.

18.Ibid. Mr. Whitley said that when this occurred, the hydrogen gas was allowed to burn off, and electrolyte was withdrawn from the cells to avoid loss of zinc through re-solution.

19.Udell, "Zinc Processes Compared," 13, in "Zinc Report, 1923".

20.Ibid.

21.Udell, "Tainton-Pring Process," 69, in "Zinc Report, 1923." Woolf further noted (on 71-72) that Tainton had conquered the gelatinous silica problem by precipitating it out with the addition of a reagent, which Tainton wouldn't name (for fear that anyone could appropriate the use of this low cost, low quantity substance, thus compromising Tainton's work, as it "would be quite impossible to detect its secret use by analysing the cake or filtered solution"). In his 1971 consultation, Ehrlinger identified the reagent used as calcium fluoride (p.5).

22.W.G. Woolf, "Report of Tainton Electrolytic Process on Star Ore," 23 July 1921, 1-7, P.D.S.R.

23.Ibid, 1.

24.Ibid, 2.

25.Ibid, 4.

26.Ibid, 5.

27.Ibid.

28.Woolf, "Report of Process," 6. See also Udell, "Comments Ingall's Report," 58, in "Zinc Report, 1923". Tainton addressed the cobalt precipitation problem (in a low density plant) by stating that "it would be necessary in a fifty ton plant to heat up 1250 tons of solution to near boiling point at each leaching cycle, and this would require the expenditure of 40-50 tons of coal per

day."

29.Woolf, "Report of Process," 6.

30.Ibid, 7.

31.Woolf, "Report of Process," 7.

32.Smith, "Report on the Tainton-Pring Process," in Udell's "Zinc Report, 1923" (Tainton-Pring Process section, 39).

33.John Fahey, Hecla- A Century of Western Mining, (Seattle: University of Washington Press, 1990), 60.

34.Woolf, "Report of Process," 1.

35.Ibid, 7.

36.Fahey, Hecla- A Century of Western Mining, 52-53.

37.Ibid, 53.

38."Articles of Incorporation," Sullivan Mining Company, 15 May 1917, P.D.S.R.

39.Oscar H. Hershey, "Second Report on Economic Geology of Star Mine," in Udell's "Zinc Report, 1923" ("Star Mine" section, 47-60).

40.Ibid, 59-60.

41.Ibid, 60.

42.Ibid.

43.Fahey, Hecla- A Century of Western Mining, 52-53.

44."B.H.&S.-Hecla Star Expenditures," Sullivan Mining Co. accounting memorandum to F.W. Bradley, April 6, 1922, P.D.S.R.

45.Fahey, Hecla- A Century Of Western Mining, 56-58.

46.Udell, "Summary", 1, in "Zinc Report, 1923."

47.Udell, "Star Mine", 3, in "Zinc Report, 1923."

48.Fahey, Hecla- A Century of Western Mining, 61-62.

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49. Henry P. Ehrlinger, "The Development of the Process Whereby Zinc of Exceptional High Purity is Made," unpublished engineering thesis, University of Wisconsin (1930), Madison, Wisconsin, 6-7.

50. Ibid, 6; Ehrlinger, "Bunker Hill Zinc Plant," 3.

51. "Payroll For The Period Ending July 15, 1925," Bunker Hill & Sullivan Mining & Concentrating Company, 186; "Payroll For The Period Ending Sept. 30, 1925," B.H.&S.M.&C.Co., 359. Mr. Henwood is listed as an employee of the North Mill, and Mr. Waltman appears under the "Construction and Repair" crew heading. This payroll book is stored with those from other years at the Staff House Museum in Kellogg, Idaho. See also the "Mills" section of historic Bunker Hill photographs housed in the Kellogg Public Library, which contains photographs of the North Mill staff in which Popoff, Henwood, Waltman, and other crew members appear and are identified.

52. Ehrlinger, "Bunker Hill Zinc Plant," 3-6.

53. Ibid, 3.

54. Ibid, 4.

55. Henry P. Ehrlinger and Howard D. Crawford, "Highlights of the Tainton Electrolytic Zinc Process," 4, photocopy of original owned by H. P. Ehrlinger III of Savoy, Illinois. This is an unpublished paper of 31 October 1932, submitted by Ehrlinger and Crawford to The Wisconsin Engineer, University of Wisconsin, Madison, Wisconsin.

56. Ehrlinger, "Bunker Hill Zinc Plant," 6.

57. Ibid, 7; Ehrlinger, "Development of the Process," 7.

58. Ehrlinger, "Bunker Hill Zinc Plant," 7.

59. Ibid, 8.

60. Ehrlinger, "Development of the Process," 14.

61. Ibid, 17.

62. Ibid, 19; Ehrlinger, "Bunker Hill Zinc Plant," 8. The effort to enhance purity continued beyond the pilot plant work. Strontium Carbonate (SrCO_3) was used at the Zinc Plant during the 1968-1981 period to provide further control of trace impurities in the redesigned 15,000 Amp. electrolytic cell lines (Peter M. Jasberg, interview by author, 1 July 1993, Kellogg, Idaho).

63. Ehrlinger, "Development of the Process," 21-22.
64. Wallace G. Woolf to Stanly A. Easton, "Memo: North Mill Work," 4 December 1926, 1-2, P.D.S.R.
65. Frederick W. Bradley to Stanly A. Easton, 10 March 1925, P.D.S.R.
66. W.G. Woolf to U.C. Tainton, 16 October 1926, P.D.S.R.
67. U.C. Tainton to R.E. Phelan, 4 January 1927, P.D.S.R.
68. Udell, "Butte District", 1, in "Zinc Report, 1923."
69. Ibid.
70. Bradley to Easton, 7 May 1923, P.D.S.R.
71. Bradley to Easton, 10 November 1923, P.D.S.R.
72. Bradley to Easton, 23 December 1924, P.D.S.R. In a telephone interview (23 April 1993), Paul Anderson of Washington Water Power in Coeur d'Alene, Idaho told the author that, prior to the thirties, W.W.P. was part of a larger holding company. This may have been the avenue by which Anaconda exercised its influence.
73. W.G. Woolf to S.A. Easton, 22 January 1923, P.D.S.R.
74. "Zinc Plant Power Contract," Washington Water Power and Sullivan Mining Company, 23 March 1927, 4, P.D.S.R.
75. Walter K. Mallette to S.A. Easton, 1 October 1926, P.D.S.R.
76. Ibid.
77. Mallette to Easton, 1 November 1926, P.D.S.R. The identity of the structural steel designer who performed this work has not been established.
78. Ibid, 2.
79. Mallette to Easton, 18 January 1927, P.D.S.R.
80. Mallette to Easton, 5 February 1927, P.D.S.R.
81. Ibid.
82. Ibid.

83.Ibid, 2. The identity of the electrical engineer who performed this work has not been established.

84.Mallette to Easton, 7 July 1927, P.D.S.R.

85.Ibid, 4.

86.Mallette to Easton, 5 October 1927, P.D.S.R.

87.Patrick Damiano, interview by author, 22 March 1993, Kellogg, Idaho. Mr. Damiano succeeded Steve Sivara, the original foreman of the lead-burning crew. He served in this capacity for many years, and recalled Woolf's comment, which was based on both the Smelter's use of the scrap lead, and Bunker Hill's control of Northwest Lead in Seattle (after the mid-thirties), a finished product plant and source of the sheet lead.

88.Mallette to Easton, 9 September 1927, P.D.S.R.

89.Ted Turnbow, interview by author, 27 January 1993, Kellogg, Idaho. Mr. Turnbow was a Maintenance Superintendent at the Zinc Plant for many years.

90.Mallette to Easton, 20 September 1927; Mallette to Easton, 2 January 1928, P.D.S.R.

91.W.K. Mallette to S.A. Easton, 6 February 1928, P.D.S.R.

92."Sullivan Mining Company, September 1928, (Ignoring Depreciation, Depletion and Amortization)," accounting report, P.D.S.R.. This is contained in the "Zinc Plant Reports" file that also has Mallette's Zinc Plant construction reports to Stanly Easton.

93.U. C. Tainton, "The Sullivan Electrolytic Zinc Plant," Engineering & Mining Journal 126, no. 22 (1928), 857.

94.Woolf and Crutcher, "Making Electrolytic Zinc," 73.

95.Ibid.

96.Ehrlinger and Crawford, "Highlights of the Tainton Electrolytic Process," 3.

97.Woolf and Crutcher, "Making Electrolytic Zinc," 73.

98.Tainton, "Sullivan Electrolytic Zinc Plant," 857.

99. Smith, "Report on the Tainton-Pring Process," and Woolf, "Report of Martinez Plant," in Udell's "Zinc Report, 1923" ("Tainton-Pring Process" section, 30-31, 71).

100. Woolf, "Report of Process," 3.

101. Angus Y. Bethune, telephone interview by author, 22 April 1993, Spokane, Washington. Mr. Bethune was assigned to this problem, early in his career at the Zinc Plant. He said that, although it was a valid idea, magnetic separation failed as it didn't cleanly separate the ferrite portion from the calcine. Entrained sphalerite was contained in the ferrite.

102. Ehrlinger and Crawford, "Highlights of the Tainton Electrolytic Zinc Process," 4.

103. Woolf and Crutcher, "Making Electrolytic Zinc," 74.

104. Peter M. Jasberg, interview by author, 9 August 1993, Kellogg, Idaho.

105. Ehrlinger and Crawford, "Highlights of the Tainton Process," 5.

106. Woolf & Crutcher, "Making Electrolytic Zinc," 74.

107. Ibid.

108. Ibid.

109. Tainton, "Sullivan Electrolytic Zinc Plant," 858. Woolf and Crutcher, in their 1939 E. & M. J. article, noted that these tanks were originally lead-lined (p. 74), but that those earlier tanks were replaced by "wood tanks having staves 6 in. thick without lead lining." This resulted in lower repair costs. The newer tanks were also 3 feet deeper.

110. Woolf and Crutcher, "Making Electrolytic Zinc," 74.

111. Tainton, "Sullivan Electrolytic Zinc Plant," 858.

112. Woolf and Crutcher, "Making Electrolytic Zinc," 75.

113. Tainton, "Sullivan Electrolytic Zinc Plant," 858.

114. Supra, note 63.

115. Tainton, "Sullivan Electrolytic Zinc Plant," 859.

116. Bunker Hill Company, "Electrolytic Department," 5, in "Zinc Plant Operations Data," unpublished manual (1958), P.D.S.R.

117. Ibid; Robert Nelson, interview by author, 26 July 1993, Kellogg, Idaho. Mr. Nelson worked in the cell room during the forties and fifties, when this cooling system was still in use. The method of cleaning deposits by electrically connecting the cooling cells to the electrolytic circuit had been discontinued (except for rare instances) in favor of manually dislodging deposits with hand tools.

118. "Electrolytic Cell," Sullivan Mining Company (Drawing Number 75), 7 April 1927, P.D.S.R. This sketch was drawn by Mr. Bjork, checked by Mr. Howard, and approved by Wallace G. Woolf.

119. Tainton, "Sullivan Electrolytic Zinc Plant," 859. The manganese dioxide was primarily reused in the leach tanks. Preparation of the material for marketing as an oxidizer was not a regular plant process (Ed Sullivan, telephone interview by author, 11 August 1993, Cataldo, Idaho).

120. Ibid, 858.

121. Ehrlinger, "Development of the Process," 23. The ratio of gum arabic to cresylic acid in the emulsion was 1.5 lbs. per ton/.75 lbs. per ton.

122. Ehrlinger and Crawford, "Highlights of the Tainton Electrolytic Zinc Process," 8. The method of pulling and stripping cathodes remained basically the same throughout the Zinc Plant's operating history, with one exception. By the thirties, strippers were using rubber boots and gloves, and were walking directly on top of the cells to pull cathodes, foregoing the use of the platform gangway (which remained in use for maintenance of the launders).

123. Tainton, "Sullivan Electrolytic Zinc Plant," 859.

124. Ibid.

125. Bethune, 24 March 1993. Mr. Bethune told the author that he was the first superintendent there.

126. Richard Nearing, interview by author, 8 April 1993, Kellogg, Idaho. Mr. Nearing was a salaried foreman at the Cadmium Plant during part of his career at the Zinc Plant.

127. Woolf and Crutcher, "Making Electrolytic Zinc," 76.

128. Ibid, 77. The barren solution was sometimes prepared for marketing as zinc sulfate ($ZnSO_4$), which was widely used in mine milling operations. The residue obtained from tank purification and Shriver press filtering was transferred back to the ball mill feed conveyor by wheelbarrow (Bunker Hill Company, "Cadmium Plant," 7, in "Zinc Plant Operations Data," unpublished manual (1958), P.D.S.R.

129. "Cadmium Plant," 7, in "Zinc Plant Operations Data."

130. Ibid.

131. Nearing, 8 April 1993.

132. Nearing, 8 April 1993. Mr. Nearing said that the cadmium balls were formed in a casting wheel sometime after 1960, but that the stick form remained a hand-ladling operation. A second melting pot was added to the Cadmium Plant in 1957, when the Bunker Hill Lead Smelter ceased producing refined cadmium metal and began shipping cadmium sponge to the Zinc Plant for electrowinning.

133. J.W. Gwinn and Ed Kevern, "The History of the Enterprise," in "The Bunker Hill & Sullivan Enterprise Today," Engineering and Mining Journal 140, no. 8 (1939), 39.

134. Tainton, "The Sullivan Electrolytic Zinc Plant," 856-60.

135. Ed Sullivan, interview by author, 1 March 1993, Cataldo, Idaho. Mr. Sullivan was a mechanical superintendent at the Zinc Plant for many years and a member of the original Twenty-Year Club.

136. "Zinc Plant Building & Foundation Information Map," Bunker Hill Company, (Drawing number 1056-A-L), 18 September 1968, P.D.S.R.

137. Ibid; Charles P. Blickle, "Exhibit B- Schedule of Buildings and Land Improvements," 13-15, in Appraisal Report- The Bunker Hill Company, (Milwaukee, Wisconsin: American Appraisal Company, 18 November 1977), P.D.S.R.

138. Gwinn and Kevern, "The Bunker Hill & Sullivan Enterprise Today," 39.

139. Jack Etherton, interview by author, 18 March 1993, Kellogg, Idaho. Mr. Etherton began his employment with the Zinc Plant at this time. He worked in the Research and Analytical Laboratories, and was later promoted to a supervisory position in Melting & Casting.

140.Dames & Moore, "Bunker Hill Site RI/FS Technical Memorandum, Subtask 8.1: Compilation of Process and Material Information," Document No.: 15852-PD039, 4 November 1987, Golden, Colorado, 30. While the number of cells is known, it is uncertain how many tanks and filters (Burts and Shrivvers) were added at this time.

141."Zinc Plant Building Information," Bunker Hill Company, 18 September 1968.

142.Harmon E. Keyes to F. W. Bradley, 14 November 1932, P.D.S.R.

143.Harmon E. Keyes to R. G. Hall, 1 December 1932, P.D.S.R.

144.R.G. Hall to Harmon E. Keyes, 9 January 1933, P.D.S.R.

145.Jack Clemson, interview by author, 10 March 1993, Kellogg, Idaho. Mr. Clemson, a former Maintenance Superintendent at the Zinc Plant, was on the Mechanical Crew when the Acid Plant was built.

146.Ed Whitley, Metallurgist, interview by author, 29 April 1993, Kellogg, Idaho.

147."Zinc Plant Building Information," Bunker Hill Company, 18 September 1968.

148.Bunker Hill Co., "Roaster Department," 5, in "Zinc Plant Operations Data," unpublished manual (1958), P.D.S.R.

149.Ibid.

150.Ibid.

151.Bunker Hill Co., "Acid Plant," 4, in "Zinc Plant Operations Data," unpublished manual (1958), P.D.S.R.

152.Ibid.

153.Ibid, 6.

154.Ibid, 6.

155.Ibid.

156.Peter M. Jasberg, Engineer, interview by author 7 April 1993, Kellogg, Idaho. Mr. Jasberg was involved in many facets of work at the Zinc Plant during his career there. Of the various process steps in the Zinc Plant flowsheet, this was one developed solely by Bunker Hill.

157.Ibid. The leaching of magnesium carbonate was required for magnesium removal from the concentrate. After that had been accomplished the concentrates entered the regular Zinc Plant process chain.

158.Bunker Hill Co., "Pretreatment Department," 2, in "Zinc Plant Operations Data," unpublished manual (1958), P.D.S.R.

159.Ibid, 3.

160.Ehrlinger, "Development of the Process," 15.

161.Robert L. Bird, "Electrolytic Zinc Plant Gets a New Look," Engineering & Mining Journal 170, no. 5 (1969), 87.

162.Peter M. Jasberg, interview by author, 28 July 1993, Kellogg, Idaho.

163."\$8,000,000 Zinc Plant Expansion Planned," Bunker Hill Reporter 10, no. 9 (1965), 1. The Bunker Hill Reporter was a monthly newspaper issued by Bunker Hill's Employee and Public Relations Division. Bound copies are on file at the Kellogg Public Library, Kellogg, Idaho.

164.Robert L. Bird, "The Bunker Hill Electrolytic Zinc Plant," unpublished paper presented at the 74th Northwest Mining Association Convention, Spokane, Washington, December, 1969, 3, P.D.S.R.

165.Pete Jasberg, interview by author, 1 July 1993, Kellogg, Idaho. During the period 1960-81, Mr. Jasberg investigated the substitution of lightweight synthetic materials for lead and wood throughout the Electrolytic division of the Zinc Plant.

166.P. M. Jasberg, "Revised Electrolytic Cell Design- Zinc Plant," unpublished Bunker Hill Company report, circa 1966, 1, P.D.S.R.

167.Ibid, 2.

168.Woolf & Crutcher, "Making Electrolytic Zinc," 75.

169.Tainton, "Sullivan Electrolytic Zinc Plant," 858; Woolf and Crutcher, "Making Electrolytic Zinc," 75.

170.Jasberg, "Revised Electrolytic Cell," 3.

171.Bird, "Bunker Hill Electrolytic Zinc Plant," 5.

172. Robert "Spec" Smith, interview by author, 30 March 1993, Kellogg, Idaho. Mr. Smith was a Leach/Purification general foreman when continuous leaching was implemented.

173. Dames & Moore, "Bunker Hill Site RI/FS Technical Memorandum," 27.

174. Robert "Spec" Smith, telephone interview by author, 2 August 1993, Pinehurst, Idaho.

175. Bird, "Bunker Hill Electrolytic Zinc Plant," 1.

176. Stan Edwards, telephone interview by author, 7 July 1993, Pinehurst, Idaho. Mr. Edwards helped to implement the incentive plan in the Cell Room. This was followed by a similar incentive plan for cell repair crew workers in 1974.

177. Jasberg, 1 July 1993.

178. P. M. Jasberg, interview by author, 2 August 1993.

179. Walter K. Mallette, "Electrolytic Zinc Plant Construction Cost Accounts," 23 May 1927, 3, P.D.S.R.

180. P. M. Jasberg, interview by author, 2 August 1993, Kellogg, Idaho (Mr. Jasberg worked with Mr. Lauer during summers as a student employee); "First Annual Meeting and Dinner of the Zinc Plant 20 Year Club, Dining Room, Union-Legion Building, Kellogg, Idaho, March 15, 1949," Zinc Plant 20 Year Club scrapbook kept by Wayne Bushnell of Kellogg, Idaho.

181. Mallette to Easton, 19 July 1927, P.D.S.R.

182. Mallette to Easton, 20 October 1927, P.D.S.R. A seventh home for Zinc Plant staff, south of the first six, was built in the forties (P. M. Jasberg, interview by author, 2 August 1993, Kellogg, Idaho).

183. Henry P. Ehrlinger, III, telephone interview by author, 26 April 1993, Urbana, Illinois. Mr. Ehrlinger is currently on the staff of the Illinois State Geological Survey in Urbana, Illinois.

184. Robert Kenneth Carpenter, Metallurgist, telephone interview by author, 29 April 1993, Herculaneum, Missouri. Mr. Carpenter worked at the East St. Louis plant (now identified as being in Sauget, Illinois) after 1940.

185. "Dr. Tainton Burial Today," Baltimore Sun, 1 September 1945, Baltimore, Maryland.

186."Metallurgical Post Goes To Bethune," Bunker Hill Reporter 2, no. 2 (1957), 3.

187.Bethune, 24 March 1993.

188."Obituary," Deseret News, Salt Lake City, Utah, 17 September 1990, B4.

189.Jasberg, 1 July 1993. Henwood was well liked by those who served under him, and he was often a source of information on the subjects that he gained a knowledge of through his private research.

190.Sullivan, 1 March 1993. As of 1993, Mr. Sullivan is one of four surviving members of the original Zinc Plant Twenty-Year Club, the others being Angus Bethune, Pat Damiano, and Ward Williams.

191.Etherton, 18 March 1993. Mr. Etherton worked with both of these men in Zinc Plant Research during his own extensive career with Sullivan and Bunker Hill.

192.Arthur Bisaro, interview by author, 15 March 1993, Kellogg, Idaho.

193.Woolf and Crutcher, "Making Electrolytic Zinc," 74.

194.Bisaro, 15 March 1993. Mr. Arthur Bisaro also plied the bricklayer's trade at the Bunker Hill Lead Smelter, where he was a Maintenance superintendent.

195."Payroll December 'B' 1937," Sullivan Mining Company Electrolytic Zinc Plant, p. 1587, Staff House Museum, Kellogg, Idaho (Mr. Kilimann was employed on the Warehouse staff); Robert Graves, telephone interview by author, 3 August 1993, Kellogg, Idaho (Mr. Graves began working in Accounting for Sullivan in 1948); Gerald Turnbow, telephone interview by author, 3 August 1993, Pinehurst, Idaho (Mr. Turnbow worked as a laborer in Maintenance during summers and after school, starting in 1944); "Bunker Hill Personnel Records," DeVries Business Records, Spokane, Washington (Mr. Halley was employed at the Zinc Plant from 6/14/51-8/26/51, when he was a college student).

196.Jasberg, 1 July 1993.

197."First Annual Meeting and Dinner of the Zinc Plant 20 Year Club, Dining Room, Union-Legion Building, Kellogg, Idaho, March 15, 1949," program contained in the Zinc Plant 20 Year Club Scrapbook, originated by Vernon Roehl, maintained by Wayne Bushnell, Kellogg, Idaho. Twenty-Year Club members not shown in the photograph of ID-

28-7 were: Hugh Crozier, Lenoir J. Fisher, Stephan Hansen, Walter Leamy, Nan McClung, Benjamin Rozelle, and Walter Siegfried. These members names were listed on the program that was printed for the inaugural meeting.

198.Bird, "Bunker Hill Electrolytic Zinc Plant," 1.

199.Ehrlinger, "Development of the Process," 1.

200.Bethune, 24 March 1993. Mr. Bethune used the example of the carburetor, estimating that it could conceivably cost \$8,000.00 to machine an eight-barrel carburetor. Mass produced die cast carburetors were priced in the \$75.00-100.00 range.

201.Jasberg, 1 July 1993; Etherton, 18 March 1993. Among Mr. Allen's castings were zinc Bunker Hill donkeys and zinc Idahos.

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"Joplin Test October 22, 1927, Back row: _____, Henwood, Leamy, Kelso, _____, Patten, Woodward, Taylor, Ehrlinger, Popoff, Nothing. Front row: Crozier, Hunter, Woolf, E. Waltman, Wadsley, Crutcher." Photograph contained in "Mills" section of Bunker Hill photograph collection, Kellogg Public Library, Kellogg, Idaho.

"North Mill 1927 Joplin Test." Photograph contained in "Mills" section of Bunker Hill photograph collection, Kellogg Public Library, Kellogg, Idaho.

The above two photographs are identical, with the second photo having some of the names written on its face.

"Original North Mill crew that worked on electrolytic process- 1922. Wallace Woolf on left A. B. 'Curly' Henwood in center." Photograph contained in "Mills" section of Bunker Hill photograph collection, Kellogg Public Library, Kellogg, Idaho.

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